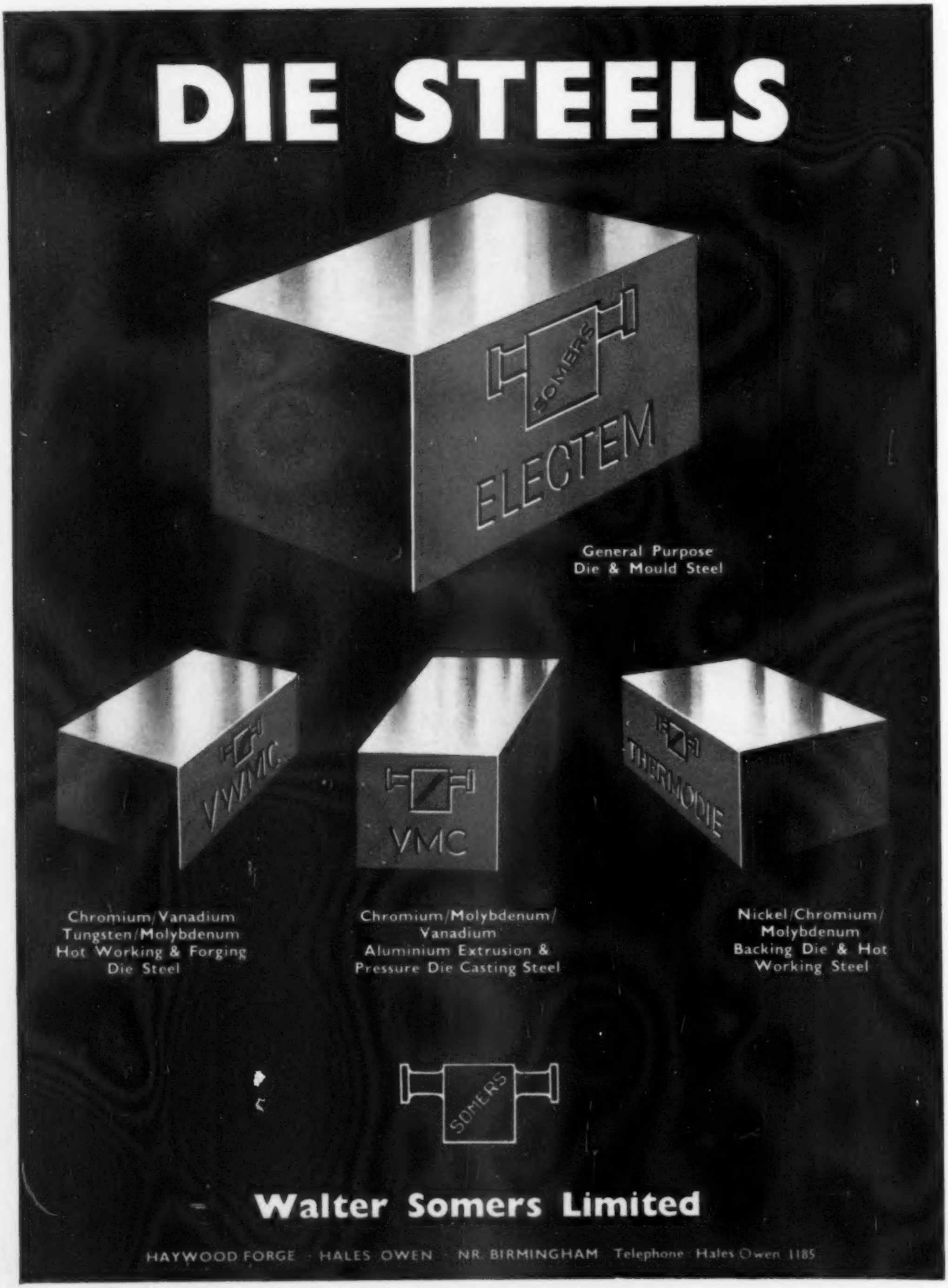
metal treatment and Drop Forging

Vol. 28 : No. 193 OCTOBER, 1961 Price 2/6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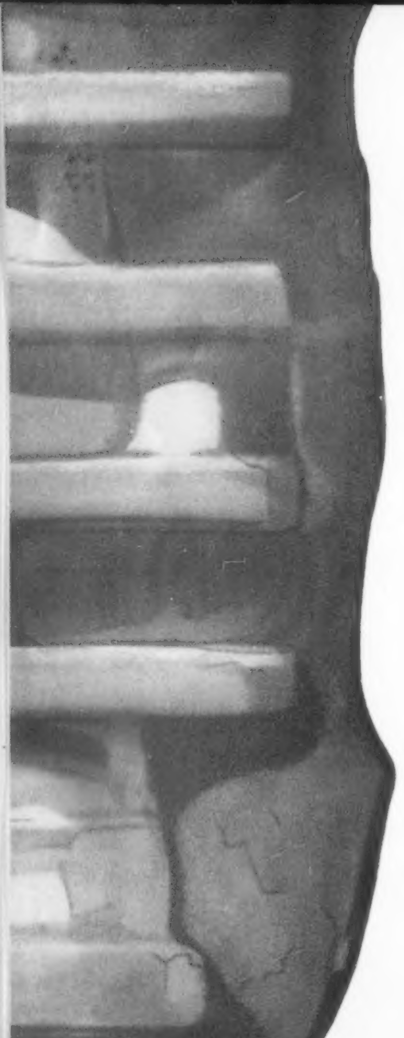

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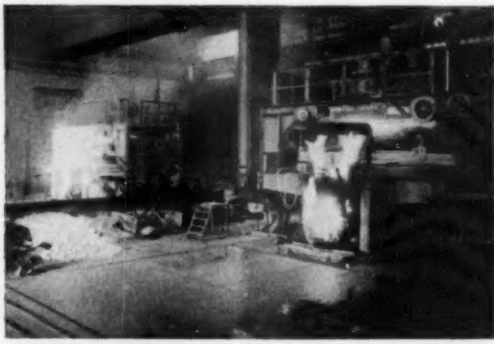
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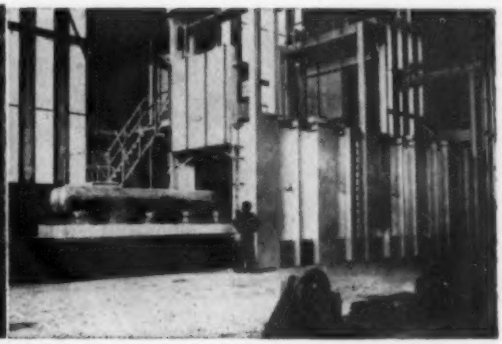
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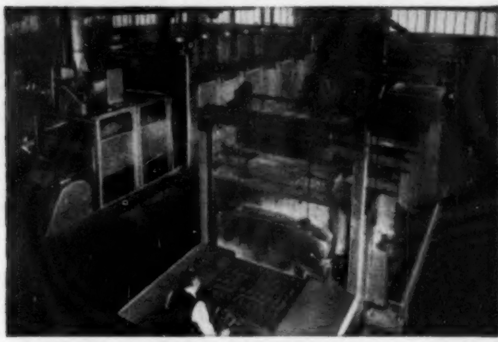
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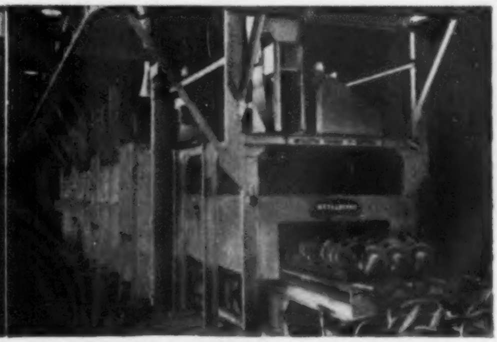
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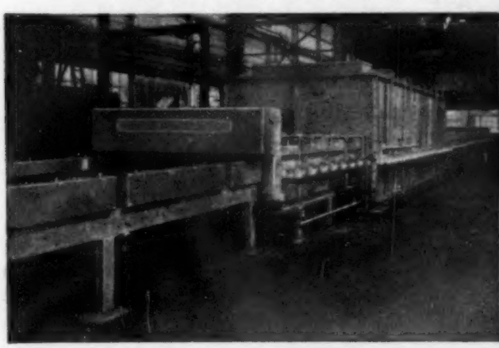
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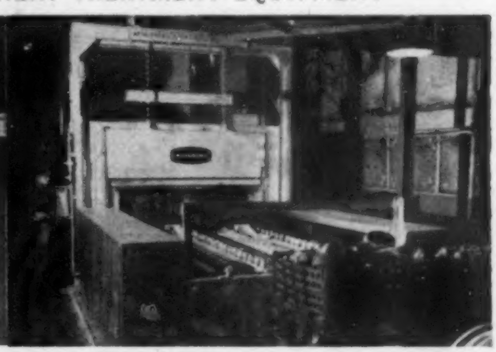
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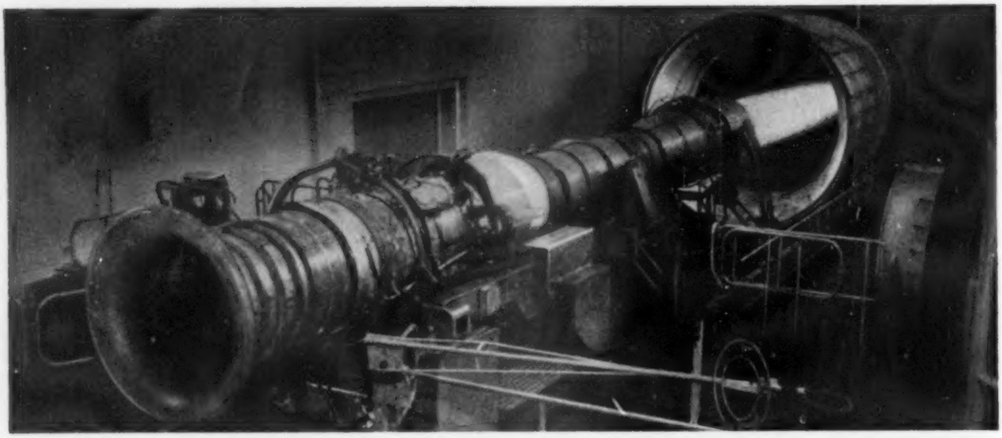


An Olympus 201 turbojet engine on test at the Patchway, Bristol, factories of Bristol Siddeley Engines Limited

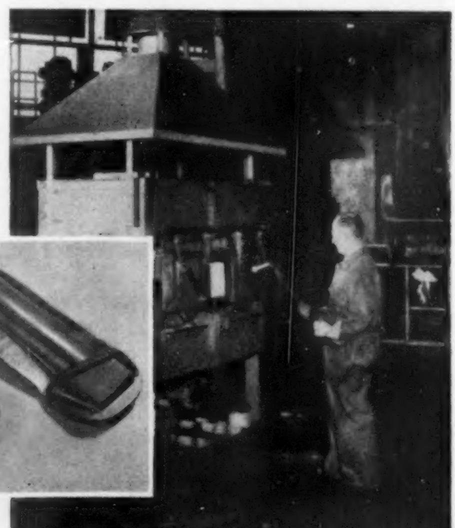
The Metallurgical Problems of Gas Turbine Engines

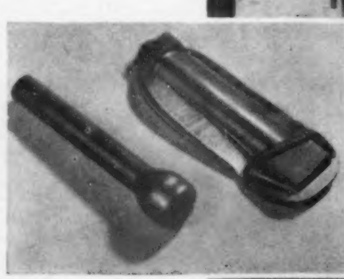
"That gas should be so extensively used is an indication of its versatility and excellence as a precision heating fuel"

Many such problems are encountered by Bristol Siddeley Engines Ltd., a company formed as recently as April 1959 by the merger of Bristol Aero Engines and Armstrong Siddeley Motors, which were the respective aero engine manufacturing companies of the Bristol Aeroplane Company and the Hawker Siddeley Group. The new engine company is one of the largest of its kind in the world and offers an extremely wide range of propulsion units both for manned aircraft and missiles.

There is no doubt that in aero engine manufacture the limitations are almost entirely those of the performance of new alloys and the ability to form and process these alloys satisfactorily. The turbine and rotor blade forge shop at the Patchway Works houses four forging presses varying from 800 to 1,000 tons and six drop hammers from 400 to 2,000 lb. These are fed from ten gas fired muffle furnaces operating through a range of temperatures from as low as 450°C for the low temperature aluminium alloys to 1150°C for the high nickel alloys. In this shop aluminium alloys are heated by air circulation furnaces while Nimonic, stainless steel and titanium alloys are processed in muffle furnaces. The variety of blade lengths ranges from ½" to 12" in overall length, and for some of the alloys a reducing atmosphere is required and obtained from cracked ammonia. The number of blades in a typical engine varies from 1,000 to 2,500 and these represent the number of potential points of a failure if one of these blades is incorrectly formed and processed. The whole of the forge shop uses gas for heating the dies as well as the furnaces, and as was pointed out by one of the engineers, the temperature time sequence using heat resisting alloys particularly is very critical. The soaking period must be

Heating for first forging in a 1,000 ton friction screw press in the Blade Forge Shop of Bristol Siddeley Engines Limited, Patchway, Bristol.





adequate but it must not exceed a defined period. Gas with its uniform calorific value and its ability to be supplied at a governed pressure facilitates the problems of automatic temperature control on those soaking furnaces.

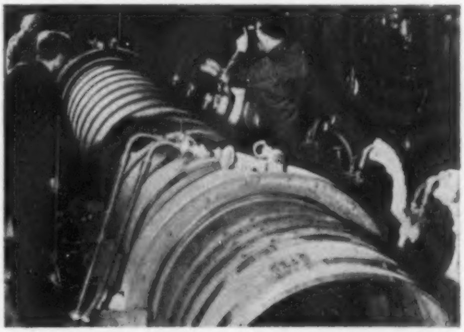
The precision foundry at Patchway also uses considerable quantities of heat resisting alloys for rotor blades and here gas is used exclusively for mould firing with a time cycle of four to eight hours at a temperature of 1000 to 1050°C. Quite recently two new mould firing furnaces were installed as a result of satisfaction with the former gas fired furnaces. In addition, a gas fired rotary sand dryer operating at 350°C provides hot sand used for melting out the wax from the shells in the lost wax moulding process. As will be appreciated, there is a certain amount of scale removing necessary, particularly on the components made from heat resisting steels. For this purpose use is made of the sodium hydride process. Basically, this involves preheating the components to drive off moisture and then immersing in a bath of molten caustic soda to which metallic sodium is added. Hydrogen, made by cracking ammonia is led into the mixture of caustic soda and sodium causing the formation of sodium hydride. The action of this material on the surface of the heat resisting steel components is to convert the oxide scale directly into spongy metal without in any way attacking the metal surface. This is advantageous in terms of the maintained precision of the dimensions of the components, and its other advantage is that a 48 hour sequence by the acid methods is replaced by a 4 hour sequence using the sodium hydride process. The temperature is maintained in the bath, which holds seven tons of the molten material, by four manifolds at the corners of the bath, each of which houses five gas burners.

The other essential features of any gas turbine engine are, of course, the jet pipes which again are made from heat resisting alloy. During the fabrication of these tubes up to 30 in. in diameter and from 15 to 20 ft. in length there is a multitudinous number of seam welding operations and it is essential that these welds are stress relieved before the component goes into service. One way of doing this would be to build a large pit furnace which is expensive in terms of capital outlay and occupies permanent valuable factory space. The Company, however, collaborated with the Industrial Engineers of the South Western Gas Board and between them made use of ring burners which had been employed in an entirely different operation in an entirely different industry. The completed jet tubes are held in position over circular gas jets, each of which is in two semi-circular segments. One end of the tube is attached to a revolving holder and the whole tube is capable of revolving round the complete circle of gas flames. These circular burners can be positioned over the various banks of welds in the tube and the stress relieving operation using gas and compressed air is carried out at a temperature of 950°C. According to the different diameters of the jet tubes, so different diameters of circular burners are used. This is a particular example of how the knowledge of the Industrial Gas Engineers of one industry can be directly applied to another.

In the sheet metal shop, as part of the bright annealing process, town gas is burnt and passed through a catalyst, and burnt after which moisture is removed from the combustion products, so providing the necessary neutral atmosphere in the bright annealing furnaces which ensures that the heat resisting steel components emerge after annealing with a bright surface completely free from scale.

Apart from these above mentioned processes, considerable use of town gas is made by Bristol Siddeley Ltd. at their Patchway factory muffle furnaces, continuous paint stoving ovens, oxy-gas profile flame cutters for many heat treatment processes, and for a variety of salt baths, degreasers and metal processing tanks.

In aero engine design and manufacture the metallurgical problems are considerable and ultimate performance depends upon the condition of the final surface of the metal while this, in turn, depends very largely on the manner in which it is heat treated and finished. That gas should be so extensively used is an indication of its versatility and excellence as a precision heating fuel.



Jet pipe weld annealing plant in No. 1 Shop at the Rodney Works of Bristol Siddeley Engines Limited.

Bristol Siddeley Engines Ltd. acknowledge the constant help which they receive from the Industrial Engineers at the South Western Gas Board and, of course, throughout the vast range of processes employing gas in industry, users and potential users of gas can obtain expert technical advice, quite freely, from their Area Gas Board.

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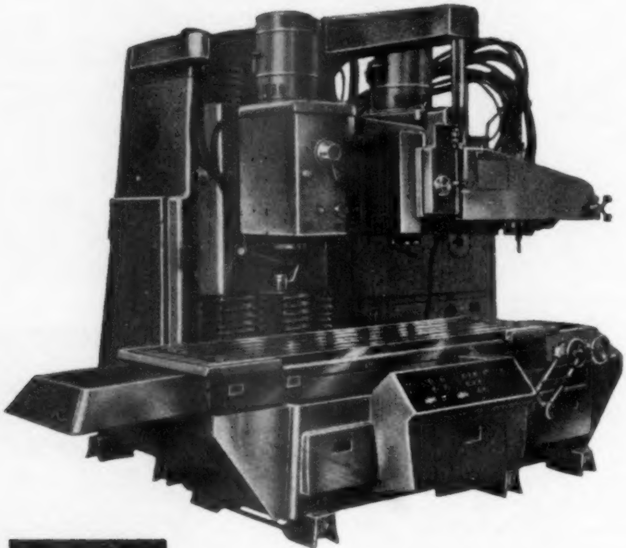

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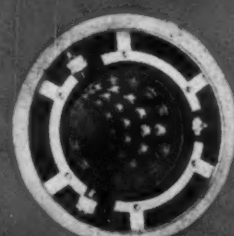

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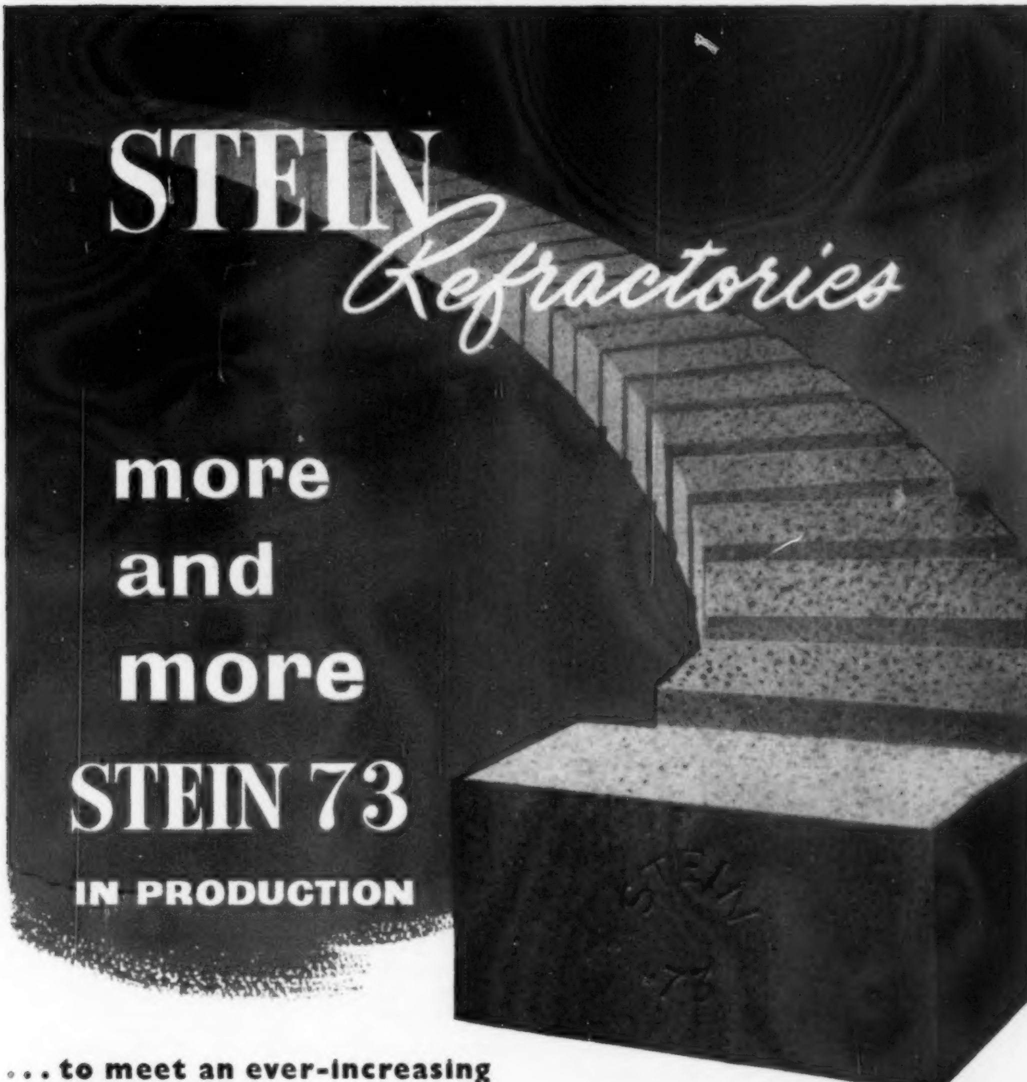

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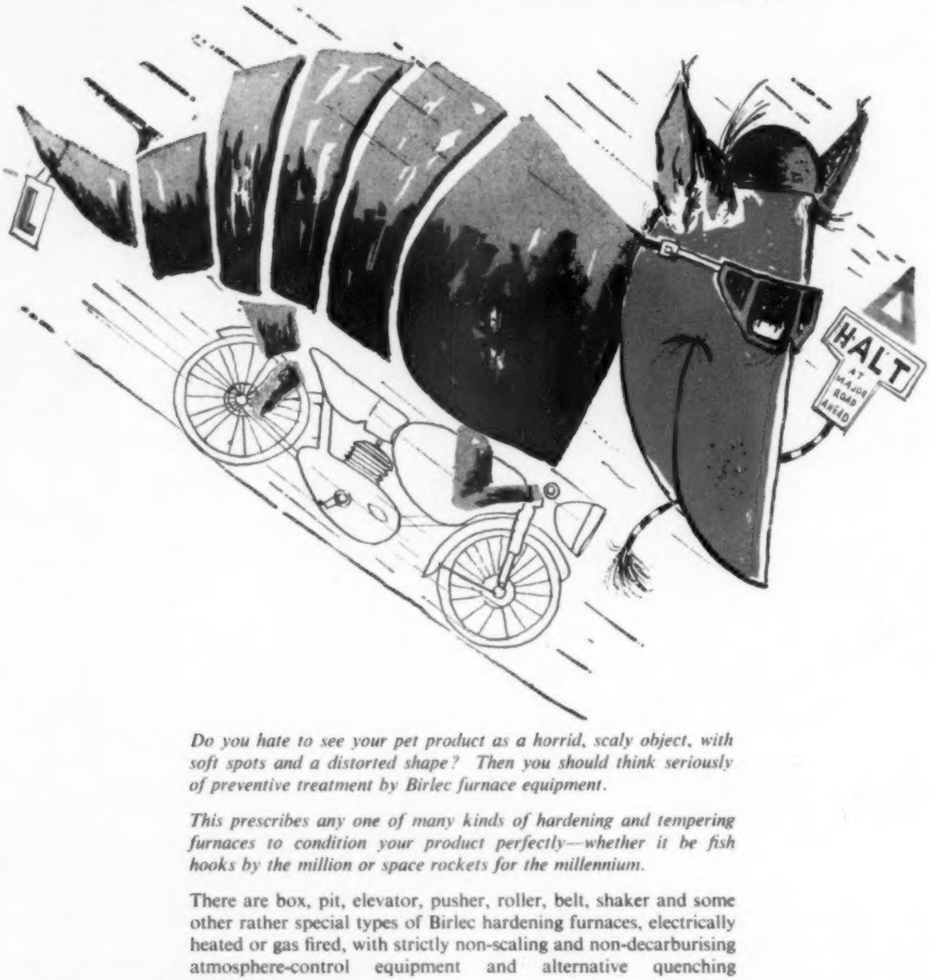

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October, 1961

Vol. 28, No. 193

Metal treatment
and Drop Forging

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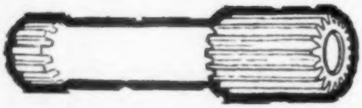

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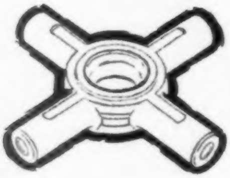

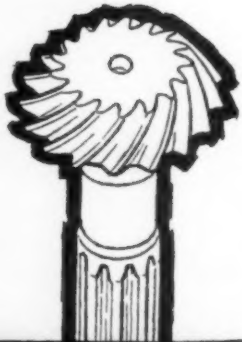

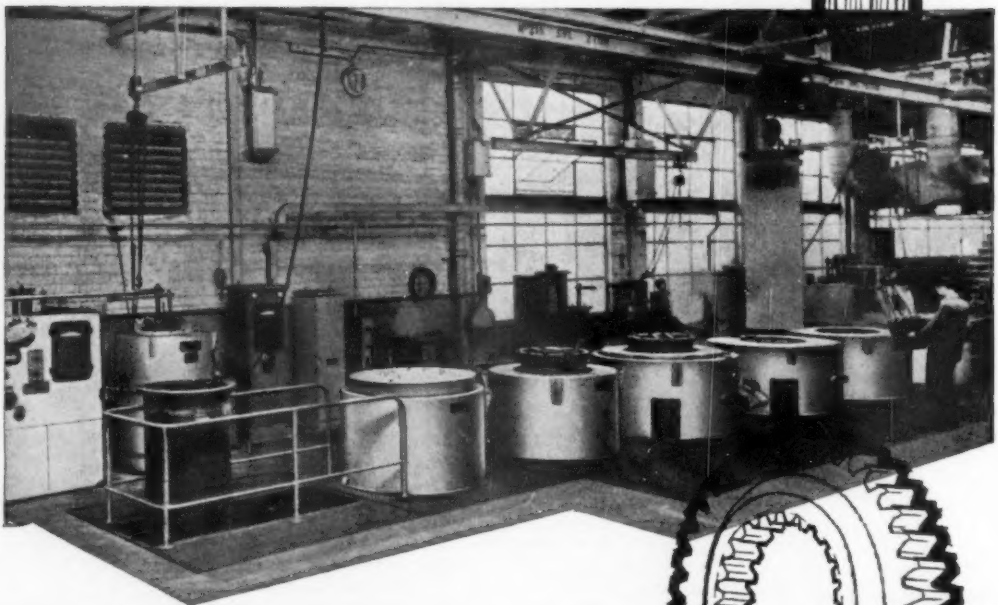

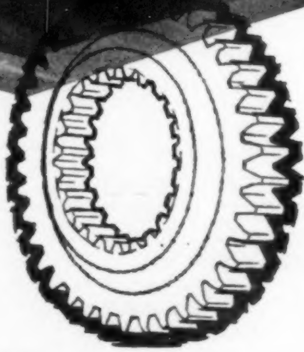

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Training centres

HAVING 'cried wolf' on educational matters rather insistently in these pages recently, it is pleasant to be able to record a recent instance of foresight on the part of an industrial concern. At any one time, the Pressed Steel Co. Ltd. has up to a thousand people under some form of training and, to ensure adequate facilities to provide for the increasing intake of apprentices, a new five-storey training centre has just been completed at Cowley, Oxford. The centre, an excellent example of contemporary design, is a model of the realistic contribution which industry can make when its responsibilities are accepted with courage.

The official opening, last month, was by the President of the A.E.U., Mr. W. J. Carron, K.S.G., M.A., who had the following interesting things to say on the necessity for craft apprenticeship.

With notable exceptions we, as a nation, had been somewhat slow in realizing the necessity to provide levels of training consistent with the accelerating rate of change which was such an outstanding characteristic of the 20th century. The rapid industrial development of many nations now enabled them to compete with us on at least equal terms, accompanied by their significant economic growth, while ours had, in the last few years, been so low as to be virtually stagnant. A major contributory factor was the country-wide dearth of trained personnel.

Special tribute was to be paid to technical colleges whose work, often under adverse conditions, had performed a service to manufacturing industry, and especially engineering, which could not be overrated. Invaluable though the educational services were, they, of themselves, could not give the practical training and experience essential to create the personnel required to man industry. Particularly was this so in the field of craft training, and he believed that a measure of craft training was of advantage to all concerned with the manufacturing side of engineering, including the highest levels.

It was understandable, said Mr. Carron, that his major interest and that of his Union was in craft training. Over the years, they had pressed for better training facilities and no limit to promotion opportunities. They had asserted, and still stressed, that employers who could not, or who would not, provide facilities for first-class craft training had no right to be entrusted with apprentices. In his estimation it was little short of criminal to enrol young people as apprentices and fail to train them adequately.

They, therefore, welcomed with enthusiasm the provision of first-class facilities by progressive companies. Buildings well designed for their specific purpose; apparatus, not, as in the past, old scrap deemed good enough for apprentices, but of the best and most modern kind; syllabuses designed to achieve maximum results by the elimination of useless effort and, most important, the choice of instructors with the ability to transmit their craft.

Mr. Carron did not accept the view that craft training should be carried out entirely in centres established solely for that purpose and divorced from actual manufacturing units. He welcomed the period spent in a well-equipped apprentice training centre prior to introduction into the works, but considered that actual contact by the apprentice with the ordinary day-to-day processes was essential to produce first-class craftsmen.

In conclusion Mr. Carron gave his views on training for newer skills. Newer skills were a development of basic craftsmanship. If sound basic training was given in the fundamental essentials of a craft then the trained skill could be applied to the requirements of the times. Experience had shown that the well-trained craftsman could adapt himself to changing techniques. In fact, it was often the craftsman himself who initiated newer methods and provided the basis of newer techniques. In this respect, he would say that the contribution of training centres of the kind provided by the Pressed Steel Co. was invaluable.

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They, therefore, welcomed with enthusiasm the provision of first-class facilities by progressive companies. Buildings well designed for their specific purpose; apparatus, not, as in the past, old scrap deemed good enough for apprentices, but of the best and most modern kind; syllabuses designed to achieve maximum results by the elimination of useless effort and, most important, the choice of instructors with the ability to transmit their craft.

Mr. Carron did not accept the view that craft training should be carried out entirely in centres established solely for that purpose and divorced from actual manufacturing units. He welcomed the period spent in a well-equipped apprentice training centre prior to introduction into the works, but considered that actual contact by the apprentice with the ordinary day-to-day processes was essential to produce first-class craftsmen.

In conclusion Mr. Carron gave his views on training for newer skills. Newer skills were a development of basic craftsmanship. If sound basic training was given in the fundamental essentials of a craft then the trained skill could be applied to the requirements of the times. Experience had shown that the well-trained craftsman could adapt himself to changing techniques. In fact, it was often the craftsman himself who initiated newer methods and provided the basis of newer techniques. In this respect, he would say that the contribution of training centres of the kind provided by the Pressed Steel Co. was invaluable.

Electron probe X-ray microanalysis

I. Segregation in ball-bearing steels

ROLAND KIESSLING and SVEN BÆCKSTRÖM

A SYSTEMATIC investigation of the use of electron probe X-ray microanalysis in different fields of metal research is at present carried out at the Swedish Institute for Metal Research. Problems of interest for the industry are selected by a committee, working within the research programme of the Swedish Ironmasters' Association (Jernkontoret) of which committee one of the authors (R. K.) is chairman and the other a member. The instrument used at the Institute, an electron probe X-ray microanalyser of the 'Cameca' design, has recently been described.[1] The general principles for this type of microanalysis, including the main correction factors, were also indicated in the same article. The committee has considered the microanalysis of segregations to be one of the fields where this type of analysis could be of great value, especially in combination with the more classical methods of metallographic investigation, *e.g.* microscopy and X-ray diffraction analysis. As an example, a ball-bearing steel showing segregation streaks was supplied for analysis by SKF Hofors Bruk.

The steel used was an annealed chromium steel with the following analysis: C = 0·98%, Cr = 1·52%, Si = 0·33%, Mn = 0·32%, P = 0·022% and S = 0·017%. In fig. 1 segregation streaks appearing dark after etching in alkaline picrate and mainly consisting of small cementite grains ($<1\ \mu^2$) are visible. Occasionally carbide particles of much greater size than the small cementite grains appear in the dark streaks, showing a marked prolongation in the rolling direction. Their section in the structure studied (fig. 1) had an area of about $5 \times 50\ \mu^2$. They do not etch dark in alkaline picrate, whereas the small cementite particles appear coloured or dark after etching. Also grey particles of MnS appear in these dark streaks which correspond to the last solidified parts of the ingot. Their section had an area of about $2 \times 40\ \mu^2$. Segregations of this type appear, if the steel is slowly cooled from the austenitic range, whereas they disappear if the cooling speed is increased. In the homogeneous austenitic range carbon is evenly distributed but it is evident from the carbide segregations that it is concentrated in the last solidified parts of the ingot if the diffusion time is long enough. This indicates that the dark streaks are enriched in some alloying element which forms stronger metal-carbon bonds than iron.

Westgren, Phragmén and Negresco[2] have studied the chromium distribution in ball-bearing steels of a composition similar to the steel under investigation. They concluded that the main part of the chromium in an annealed ball-bearing chromium steel was contained in the carbide. From X-ray diffraction analysis they also concluded that the large particles (called 'double carbide' or 'carbide accumulations') consisted of unevenly distributed cementite and that the iron in the cementite had been partly substituted by chromium.

Experimental results

A quantitative chromium iron and manganese analysis by the electron probe was carried out along a series of spots in the structure, the spots situated in lines similar to the line indicated in fig. 1. The point focus of the beam had the smallest possible size, 1 μ^2, and the points of measurement were chosen on the darker or lighter streaks of the structure, as well as on the large carbide and sulphide particles.

The results are summarized in table 1.

In fig. 1 the variation in chromium content along the line indicated in the structure is given. The

This article has been slightly abridged from two communications from the Swedish Institute for Metal Research, in *Jernkontorets Annaler*, 1961, (5). Mr. Bæckström is head of the laboratory, SKF Hofors Bruk.

TABLE 1 *Electron-probe analysis of structure components (%)*

Structure component	Chromium	Iron	Manganese
Light streaks	1 –1·5	93–95	0·3–0·5
Dark streaks	2·0–7·0	~85	0·3–0·5
Large carbide particles ('accumulated carbides')	29–34	50/56	*
Sulphide particle ..	*	~5	40

* Not measurable

observed values were corrected for dead time and background. The chromium-iron values were also corrected for fluorescence according to the formula given by Castaing.[3] It is to be observed that even if the size of the point focus of the electron beam was about 1 μ^2, radiation from a half sphere with a diameter of about 4 μ due to scattered radiation was registered. Therefore, the analytical results for the different parts of the structure varied within certain limits as the beam usually covered more than one phase or concentration region. The results are at present to be regarded only as an indication of the segregation as well as of the composition of the phases, but some conclusions may be of interest.

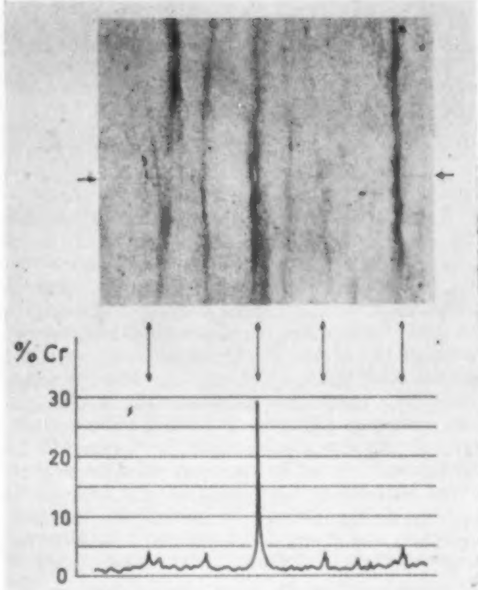
Conclusions

1. Chromium segregates in the structure and is concentrated in streaks that after annealing appear dark in etched sections (alkaline picrate) due to a concentration of cementite particles in these regions. This agrees well with the results from chemical analysis of carbide isolates from ball-bearing steel by Westgren *et al.*[2] who concluded that in an annealed ball-bearing steel about nine-tenths of the chromium content is contained in the carbide. The electron probe technique seems to be excellent for following segregation of this type.

2. The large carbide particles by Westgren *et al.*[2] called ' double carbide ' or ' carbide accumulations ' and assumed to be (Fe, Cr)$_3$C have a much higher chromium content than 18% which seems to be the maximum amount observed, if chromium replaces iron in cementite.[4] However, the formula calculated for a carbide containing 34 weight % of

TABLE 2 *Chromium and iron content (%) of the possible carbide phases if the chromium-iron ratio is assumed to be 34 : 56, as compared with the observed composition of 'carbide accumulations.' The limits for the chromium content of the different carbides according to literature are given in the last column*

Carbide phase	Cr	Fe	Cr-content
(Fe, Cr)$_3$C (calc.)	35·3	57·9	0– 18[4]
(Cr, Fe)$_7$C$_3$ (calc.).. ..	34·5	56·9	28–100[5]
(Cr, Fe)$_{23}$C$_6$ (calc.) ..	35·6	58·9	65–100[4]
' Carbide accumulations '	29–34	50–56	



1 *Etched section (alkaline picrate) of annealed ball-bearing steel specimen, showing dark segregation streaks, white 'carbide accumulations' and grey MnS particles. The chromium content obtained by electron probe analysis through point-by-point analysis along the line indicated on the section has been graphically represented. The results show relation between chromium content and segregation streaks as well as a high chromium content of the 'carbide accumulation'*

chromium, 56% of iron and the rest carbon agrees well with (Cr, Fe)$_7$C$_3$. This carbide is also the only chromium-iron carbide where the observed chromium-iron ratio of 34 : 56 falls within the limits of earlier observations (table 2). We therefore conclude that the ' double carbide ' or ' carbide accumulations ' occasionally found in ball-bearing steels is the carbide (Cr, Fe)$_7$C$_3$ and not (Fe, Cr)$_3$C.

This observation of the nature of the ' carbide accumulations ' is in agreement with the results by Bowers.[5] He reported that trigonal carbide (Me$_7$C$_3$) begins to form when the Fe$_3$C contains 19–20% of chromium and that the trigonal carbide can contain as little as 28% of chromium.

3. Any manganese segregations related to the light and dark streaks were not observed. The MnS particles were too narrow to allow any thorough analysis. The iron content observed may be due to surrounding phases containing iron.

Thanks are due to Mr. N. Ståhl for valuable assistance.

2. *Segregation in Al-Zn-Mg alloys*

ROLAND KIESSLING and NILS STÅHL

A MICROSCOPIC investigation of aluminium-zinc (5%)-magnesium (1·2%) alloys, carried out at AB Svenska Metallverken, Finspång, had shown that small chromium additions had a marked influence on the microstructure of the alloys.[6] The area near the grain boundaries etched in a characteristic way if the alloys had a small chromium content whereas no such effect was found if the alloys were chromium free. The metallographic investigation indicated that chromium additions resulted in grain segregation, a result which also has been reported by Rosenkranz.[7, 8] The purpose of the electron probe analysis was to study if any segregation existed, if segregation was related to the grain structure, and if any difference could be observed between alloys containing chromium and free of chromium.

Experimental

Two aluminium alloys, cast semi-continuously with watercooling under identical conditions at AB Svenska Metallverken, Finspång, were investigated. They had the composition given in table 3.

TABLE 3 *Composition of alloys (%)*

Alloy nr	Zn	Mg	Mn	Cr	Fe	Si	Al
1	4·6	0·90	0·22	—	0·31	0·10	Bal.
2	4·9	1·2	0·25	0·17	0·32	0·17	Bal.

Specimens from the alloys in cast condition were prepared as for microscopic investigation, the final polish being done with MgO. They were not etched because of the danger of anomalous X-ray intensity effects due to the deviation from the flat surface of the specimen which usually is the result of etching. The grain structure and grain boundary phases were visible after polishing only.

Several point analyses along different lines in the structure were carried out by means of the electron probe. The lines were chosen so that they passed grain boundaries as well as grain centres, and usually had a length of about 100 μ. Along such a line about 15–25 points were investigated which means that the composition of the alloy was determined with a mean interval between the points of about 5 μ. The finest focal spot, about 1 μ^2, was chosen. The elements Zn, Mg, Cr and Mn were analysed as well as Fe and Si in the grain boundary phases.

The intensities from the different elements in the specimen were compared with standards of the pure elements. After the usual dead time and background correction, the results were corrected for the main binary metal combinations (Al-Zn, Zn-Mg, Al-Mg) according to a formula, given by Mr. Tong of the firm ' Cameca ' and taking into consideration fluorescence as well as absorption effects.

Results

Segregation Fig. 2*a* and *b* give the micrograph and values for a linear analysis in alloy nr 2 (with Cr).

In table 4 a summary of 10 similar measurements for Zn, Mg, Mn and Cr are given.

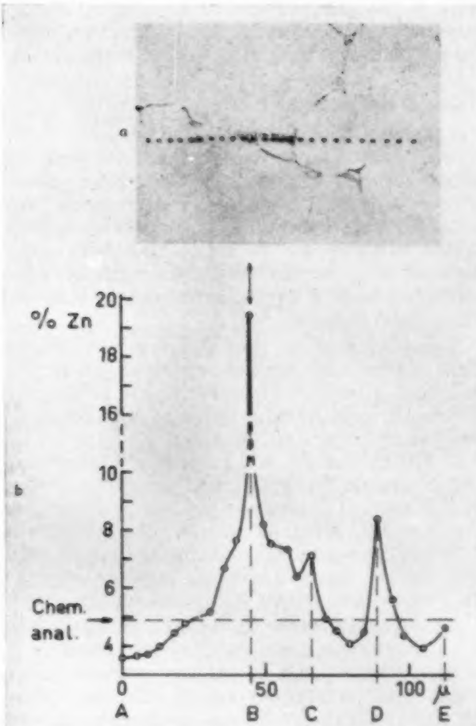
TABLE 4 *Distribution of Zn, Mg, Mn and Cr (%) in alloys nr 1 and 2. Mean values of 10 different linear analyses for each alloy, each line covering about 20 points*

Alloy nr	Alloying element	Grain centres, mean	Grain boundaries, mean
1	Zn	4·8	4·2
	Mg	0·9	0·9
	Mn	0·2	1·3
	Cr	—	—
2	Zn	3·5	8·0
	Mg	0·4	3·0
	Mn	0·2	1·1
	Cr	0·17	0·12

Although the values varied considerably for the different measurements, especially for alloy nr 2, the general trend for each linear measurement was the same as expressed by the mean values.

Grain boundary phases The metallography of the alloys under investigation is not known to such an extent that complete identification of the grain boundary phases or a knowledge of their composition of structure is possible at present.

Different suggestions about their nature have been given.[8] A thorough investigation was beyond the purpose of the present study of the possible applications of the electron probe analyser. In addition, the grains visible were too small to allow a specific determination of the grain boundary phases as the focal spot always covered more than one phase. An attempt was made, however, to find an indication of their composition by careful irradiation of different grain boundary phases. At least three different such phases were visible by



2a *Alloy nr 2 (0·17% chromium)*
Micrograph showing actual trace of electron beam (due to carbon precipitation from diffusion oil) at the different measuring points for a typical analysis
The distance between the points is about 5 μ.

b *Variation of the zinc content of alloy nr 2 (0·17% chromium) along the line shown in* **a.**
The grain boundaries are indicated by the letters B, C and D, whereas the two end points of the measuring line are marked by A and E

microscopic investigation after polishing, namely a grey phase, a black phase and a grey-white phase of which the grey lamellar phase was the main constituent.

The composition found for this phase is given in table 5 for the two different alloys investigated. The values given are the mean values of about six different measurements for each alloy. The composition and colour of the grey phase in alloy nr 1 suggests it to be 'Al_3Fe.' If it is the same phase in alloy nr 2 it is more difficult to determine. It is to be observed that it was impossible to confine the focal spot to the grain boundary phase only, and, therefore, the values have to be regarded only as indicating the trend in composition. The deviation from a sum of 100% may also depend on this difficulty, but it is to be observed that in addition to the elements given in table 5 small amounts of other elements (up to about 0·1%) as well as elements with atomic numbers below Na may be present.

TABLE 5 *Approximate composition of the main (grey) grain boundary phase (%)*

Alloy nr	Al	Zn	Mg	Mn	Fe	Si	Cr
1	68	4	2	2	22	2	—
2	55–66	15–8	2	2	22	2	Trace

In addition to the main grey phase a very fine, dispersed black phase and a grey-white phase were observed. The composition of the black phase was not possible to determine with any acceptable accuracy. It was noted, however, that it had a higher Mg- and Si-content than the grey phase and it may be 'Mg_2Si.'

The grey-white phase, finally, also consisted of very small particles located at the grain boundaries. The mean composition was independent of the presence of chromium and is given in table 6.

TABLE 6 *Approximate composition (%) of areas rich in the grey-white grain boundary phase*

Al	Zn	Mg	Mn	Fe	Si	Cr
38 ± 8	50 ± 5	15 ± 5	—	—	—	—

Because of the small particle size it was impossible to irradiate the grey-white phase alone. It was, therefore, not possible to decide whether the aluminium content observed was present in the grain boundary phase or in the matrix. The analysis is only to be taken as an indication that this phase is rich in zinc and magnesium, probably also contains aluminium, and that the elements iron, silicon, manganese and chromium are not present to any appreciable extent in the grey-white grain boundary phase. The phase may be the ternary phase '$Mg_{32}(Al, Zn)_{49}$,' reported by several authors,[9, 10] or '$MgZn_2$.'

Discussion

Zinc distribution The results clearly show that the zinc distribution in alloy nr 1 (without chromium) is rather homogeneous. A slight decrease in zinc content was noted at the grain boundaries. In marked contrast to this alloy nr 2 (with 0·17% chromium) showed a heterogeneous zinc distribution with marked segregation within the grains. High zinc concentrations were observed in or near the grain boundaries and concentrations lower than the mean zinc concentration of the alloy in the grain centres. It is to be noted that part B-C of the line in fig. 2*a* and *b* is running parallel to a grain boundary and at a distance of about 3 μ from

the boundary. The zinc content observed is considerably higher than the mean zinc content of the alloy. It is also to be observed that high zinc concentrations are observed at grain boundaries even if no precipitate is microscopically visible (see, for instance, point D, fig. 2*b*).

A study of the zinc distribution by means of electron probe analyses for an Al-Zn (18·9%) alloy has been reported in the literature.[11] An appreciable decrease in zinc content within a zone with a thickness of about 10 μ along the grain boundaries was observed (from 18·9 to 16·4% zinc). The results for the last-mentioned alloy are thus in marked contrast to the results for alloy nr 2 (with chromium) but similar to and still more accentuated than those of alloy nr 1 (without chromium).

Magnesium distribution The same tendency was observed for magnesium as for zinc. In alloy nr 1 (without chromium) the magnesium distribution was homogeneous whereas accentuated grain segregation was observed for alloy nr 2 (with chromium), with a comparatively high magnesium content at the grain boundaries and a much lower value at the grain centres.

Manganese distribution Microsegregation was observed for both alloys. The manganese had a strong tendency to concentrate at the grain boundaries for the alloy without chromium as well as for the alloy with chromium.

Chromium distribution Chromium seemed to be homogeneously distributed in alloy nr 2 and no marked segregation was observed. The small chromium content makes the difference between grain centres and grain boundaries (0·17 respectively 0·12%) insignificant, as the accuracy of the electron probe at these small concentrations is rather low.

Grain boundary phases Although the accuracy of the electron probe analysis for determining the composition of the grain boundary phases is low and the knowledge of the phases incomplete, some observations seem to be worth noticing.

From table 5 it is evident that the effect of chromium on the zinc content of the main grey grain boundary phase is the same as for the main structure, *i.e.* an increase in zinc content for the chromium-rich alloy. A higher aluminium content corresponds to a lower zinc content, and, therefore, it seems as if the zinc atoms substitute aluminium atoms. The magnesium content is too low to allow any conclusions. An important observation is that the phase contains iron to about 22% in both the alloys. Iron is not present as an alloying element but only as an impurity. Also silicon was found. The influence of these impurities may, therefore, be much greater than indicated by the chemical analysis.

It is also evident that the composition of the different phases given in earlier investigations and more or less accepted, *e.g.* Al_3Fe, $MgZn_2$, Mg_2Si, only is to be regarded as the ideal composition giving the general lattice type and structure of the phases.

General comments

The results have shown that electron probe X-ray microanalysis is an excellent method for studying microsegregation in aluminium alloys if the content of the alloying element is high enough (more than about 0·25%). Point by point analyses along lines in the structure can be carried out with point distances of 5 μ or even less and the variation of the concentration along these lines may thus be obtained with a good accuracy.

A discussion of the results from a metallurgical point of view is beyond the purpose of this article. Alloys of a similar composition were studied by Dix.[12] He investigated a 75S alloy with the composition of 5·6% Zn, 2·5 Mg, 1·6 Cu, 0·3 Mn, 0·25 Cr, balance Al, and came to the conclusion that chromium decreases grain segregation during solidification. The results of the present authors, on the contrary, seem to indicate that chromium increases grain segregation of zinc and magnesium. Dix studied wrought material, however, whereas the present observations were made on cast alloys.

An interesting observation is that although iron is an impurity and not an alloy constituent it is present in about 22% in the grey grain boundary phase. It thus probably has an influence on the physical and electrochemical properties of this phase, *e.g.* electrochemical potential, and may also be of importance to consider for such a property as corrosion resistance of the alloy. Also silicon is present to a notable extent. Electron probe analysis seems to be an outstanding method for studying the influence of certain impurities because of the possibilities to determine in which particular phase of a structure the impurities are concentrated. The results leave the impression that the influence of impurities due to their local action may be much greater than indicated by the small value from ordinary analytical methods.

The authors are indebted to Mr. Bengt Ström, head of the laboratory of AB Svenska Metallverken, Finspång, for valuable comments.

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The cold extrusion of steel

R. A. P. MORGAN, O.B.E., M.I.Mech.E.

The relatively new field of cold extrusion of steel is surveyed in this article and its techniques discussed with many practical examples. Mr. Morgan is Engineering Director of the War Department. Superintendent, R. O. F. Birtley*

INTEREST IN THE COLD EXTRUSION of steel has been increasing of late to a degree where many drop-stamping concerns and manufacturers engaged in hot forging are anxious to know what prospects this new development holds out for them and also what competition they may face from concerns engaged in cold flow forging.

The author's concern has been engaged for some years now in developing cold extrusion practices and techniques to a degree which has unlocked some of the mysteries surrounding this method of manufacturing components and, as far as possible, the process and its pitfalls are described in the following paragraphs in an endeavour to guide those entering this field. Considerable economy of material, together with increased strength characteristics, can be achieved by cold working and parts can be finish tooled off the press. In large factories engaged in considerable machining from hot forged blanks, very considerable expenditure is incurred in the manufacture of swarf and its removal from the works. This swarf is an encumbrance to any manufacturing establishment and considerable tool costs are incurred in its manufacture. A comparison of the cost of cold extrusion with standard machining methods, therefore, is not revealed by *pro rata* comparison of one method of manufacture against the other without including some factor for hidden economies, such as the reduction of swarf manufacture, which will also be achieved.

At first glance, cold extrusion appears to be very attractive and should merit serious consideration. There are factors, however, which militate seriously against its development in certain fields until the plant manufacturer has developed presses which are economically suitable for the process. This field is in connection with long, thin-walled, closed-ended cylinders. For safe and accurate working at the present time, and with presses currently available, the cold extrusion expert is faced with the fact that punch loadings are so high that their length should be kept down to no more than three times their diameter and cross-sectional area reductions of no more than 50% should be aspired to. It follows, therefore, that unless presses are designed which are automatic in sequence and will follow one extrusion operation by another, each doing a portion of the work, and finally following with one or more draw operations —cold extrusion of such components as specified cannot compete economically against high-speed machining of bar or tube stock. That is the position which cold extrusion specialists are facing up to today. The plant available has not been designed for this class of work and is therefore not economically suitable, but the day will certainly come when press manufacturers will design and market suitable presses in this country. Unfortunately in that respect we are lagging behind our competitors overseas who are already meeting this requirement. Presses are available, however, for the manufacture of other types of components where the economies to be achieved are much greater. Such components as buffer cylinders, gear blanks and the upsetting of bar stock can be economically achieved in a safe and certain manner provided the designer is prepared to turn his attention in that direction.

Crude hot forgings requiring the removal of scale and considerable machining will undoubtedly give way to cold or warm extrusion, or a combination of both, with finished surfaces direct from the tooling employed and considerable economy of material and labour can result.

Preparation for cold extrusion

Although it can be claimed, and indeed practised also in certain jobs, that more than one extrusion operation can be effected without an interstage anneal, it is not always practicable to do so without considerable 'down' time due to scoring or galling of the extrusion dies and, because of the

* Article based by the author on his lecture given at the Wolverhampton and Staffordshire College of Technology last March at a two-day symposium on 'Cold flow forming.' The article will be continued in next month's issue of METAL TREATMENT.

considerable capital investment in the plant, every moment of active production time is valuable. In small plants it is, therefore, often normal practice to carry out an anneal, followed by a combined pickle, rinse, phosphate, rinse and lubricate operation before each cold extrusion or cold draw.

These operations can be very expensive in their direct labour costs unless fully automatic plant, which can be bulk loaded, be specially purchased. Although this means more capital investment which has to be amortized or depreciated against the product cost, it is a wise investment in the long run in so far as the combined operation can be carried out relatively cheaply, as often as may be necessary and, moreover, the plant can be arranged to rock or tumble the components, which is very important if even phosphate and lubrication coatings are to be produced.

It is found to be an advantage generally to commence cold extrusion from billets produced from hot-rolled bar. The reasons are as follows. Firstly the material is cheaper than turned or cold-rolled bar. Secondly the material is already in a condition where it will withstand a certain amount of cold work without an annealing operation. Thirdly, the first degree of cold work placed upon the billet can be arranged to size it to the die for the first major extrusion operation. Fourthly, the cold work done on the billet in this condition makes the material more susceptible to easy spheroidization in the subsequent sub-critical anneal, and material properly spheroidized is considered to extrude better than if this condition is not obtained.

The first preparation for cold extrusion is obviously the cutting of the billet from bar stock. This can be achieved by sawing, shearing or parting-off. All three operations can produce billets which are reasonably volumetrically constant and it is usually capital and existing plant conditions which determine the method to be followed. For automaticity, however, in feeding into the first press, it is obvious that billets must be free from rags. Also it is essential that billets are free from tears which can represent unsoundness in the extruded component. In certain shearing operations undesirable tears result particularly when using hot-rolled bar stock. Sawing and parting-off operations always leave a rag or an upstanding centre pip on the end of the billet. Furthermore, if the sawing feed or the set of the blades is too coarse, objectional markings on the billet surface results. Trials will establish the right sawing conditions and the operation can be quite cheap, as one operator can be required to operate a number of saws. The rags and saw-cut markings can always be eliminated to present no problem at all, if the billets are properly rumbled before the first sizing operation. If the upstanding centre pip which occurs in parting-off is reasonably small, it does not present a problem in the extrusion operation as the centre portion of the billet surface does not laterally extrude very far. It can, however, be a nuisance in automatic feeding.

First press operation (*fig.* 1) This can be called the 'dumping' operation. It follows the cutting and preparation of the billet and consists of squaring up the billet, dimpling and increasing the outside diameter to a size to suit free access into the first extrusion die. As has been stated, this can be carried out without annealing and usually without lubrication on billets from hot-rolled bar stock.

The operation is useful in that it takes account of the variation in bar diameter due to the hot-rolling tolerance. It also corrects the inaccuracies inherent in sawing and shearing and establishes two dimensions A and B, as well as effecting a reasonable dimple in the top or, if the tools are reversed, the bottom face. At the same time the opposing faces of the billet are made parallel with each other and truly perpendicular to the die axis. The variation in material volume in the billets would be arranged to come at the top of the side walls and, if essential, components at this stage can be high-speed machined to length L. If necessary, an alternative base form can be produced, as shown, which will probably assist at some later operation.

The prepared billet must now be annealed, pickled, phosphated and lubricated before the main extrusion operation takes place and, as these processing operations are usually repeated without variation between any two extrusions or draw operations, a full description of the process is necessary.

Annealing This is usually carried out without the use of protective atmosphere at a temperature just below the lower critical. Thus, for ordinary low-carbon steels the annealing temperature would be about 700°C. The annealing time can be important. On a billet of about $1\frac{1}{4}$ in. dia., $\frac{3}{4}$ h. anneal is sufficient to recrystallize after cold work and to give a certain degree of spheroidization. Full spheroidization is not considered absolutely essential for steels of the 0·2% C range and below. However, if extrusion is to be carried out on a 0·3% C steel, greater spheroidization is considered necessary and an annealing time of up to 4 h. may be considered necessary. It is important to achieve the greatest degree of softening and if it is convenient to leave a batch of work in the furnace overnight, then furnace cooling should be resorted to. Quick cooling, of course, must always be avoided. Controlled atmospheres are obviously an advantage in reducing the amount of scaling which occurs, but this is not essential and has never been carried out in the work done by the author to date. The hardness of the billet after annealing is normally about 120 V.P.N. for a 0·2% C steel and

135 V.P.N. for a 0·3% C steel and this is considered suitable for normal extrusions.

Pickling This is usually carried out in a 10–15% V/V* sulphuric acid solution with an inhibitor as a prevention against hydrogen embrittlement and also to obtain an evenly pickled surface. The inhibitor used by the author is Rodine III at a ½% W/V* concentration. The temperature of the pickling solution is always 70°C. and the time of immersion is normally 10 min. In the pickling and subsequent processing operations it is important to rock or tumble the components in order to reduce as far as possible the chance of certain areas of surface being improperly treated.

Rinse after pickling This is a cold running water rinse. Time of immersion is usually 10 min.

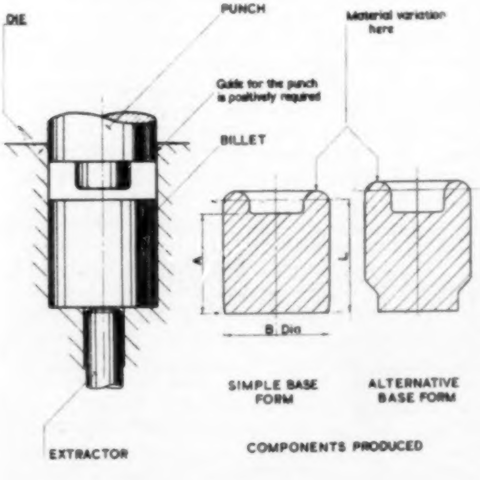
Phosphating It has been found in practice that a phosphate coating weight of about 2,000 mg./sq. ft.

*** Dilution terminology V/V and W/V**

V/V (volume by volume). *X* volumes of *A* are mixed with *Y* volumes of *B*. The unit of volume must be the same in both cases. An example being, say, a 6% V/V solution of alcohol in water. Take 6 gal. of alcohol and make up to 100 gal. with water, *i.e.* add 94 gal.

W/V (weight by volume). Indicates a difference in units, both weight and volume being employed. Typical examples being g./l., lb./gal., oz./gal., lb./100 gal., etc. A 6% W/V solution of salt in water would consist of 6 lb. of salt made up to 100 lb. with water, *i.e.* add 94 lb. It is not normal to weigh water, so convert the weight to volume, *i.e.* gallons. As the specific gravity of water is 1, and 1 gal. weighs 10 lb., the volume would be 94/10 or 9·4 gal. of water.

Similarly, the volumes of other liquids are calculated from their individual specific gravities.



1 *First press operation—dumping*

is adequate. German practice seems to indicate a lighter coating than this and there are other advocates of a heavier coating. Both of these practices have been tried out but without any improvement. Indeed, the lighter coating has been found to be detrimental, resulting in pick-up and galling of the die. Coating weights can be increased up to 4,500 mg./sq. ft. by the addition of 5% W/V sodium nitrate to the pickling solution. In most of the work carried out by the author, Bonderite 'D' series at 70 pointage and at 70°C. has been employed. The time of immersion is 10 min. The 'pointage' referred to is a measure of the free acidity and is measured by titrating against N/10 NaOH solution.

Phosphating the component alters the size very slightly and this may be of importance to the designer in so far as access into the extrusion die is concerned. In phosphating, the parent metal is reduced in volume somewhat and this is replaced in thickness by a thicker coating of phosphate. As a result the diameter of the billet will be larger after phosphating by about 0·0015 in.

Rinsing after phosphating Two rinses are employed, the first being a running cold water rinse and the second being a hot water rinse in order to bring the billets back up to temperature for the subsequent lubrication. Time of immersion is conditioned by the plant cycle and in both cases is 10 min.

Lubrication Proprietary lubricants advised by the manufacturers of the phosphating process used are considered best. Soap lubricants such as Artic soap made by Palmolive Peet are also suitable, but there is difficulty in controlling the coating weight and a too thick coating often results in fouling of the die in any automatic feeding arrangement. Because of this, the author has carried out most development work using Bonderlube 235 in a 12% W/V concentration. The Walterization DX lubricant associated with the DX phosphating process has, however, been employed with equal results.

The temperature of the bath is always 70°C. and an immersion time of 5 min. is essential to give time for the lubricant to react with the phosphate coating. It is important to ensure an even and thin coating of lubricant which dries off without tears or runs after removal from the tank. Failure to obtain this condition will certainly lead to extrusion difficulties.

Although simple lubrication as explained so far has been found to be satisfactory, an improvement in the component surface has been found to result when the billets are also dusted with a high-pressure powdered lubricant such as Abril 10 D.S. Slight evidence of stretched metal on the inner surface of the extrusion have disappeared and, as a result, more continuous production runs are experienced.

considerable capital investment in the plant, every moment of active production time is valuable. In small plants it is, therefore, often normal practice to carry out an anneal, followed by a combined pickle, rinse, phosphate, rinse and lubricate operation before each cold extrusion or cold draw.

These operations can be very expensive in their direct labour costs unless fully automatic plant, which can be bulk loaded, be specially purchased. Although this means more capital investment which has to be amortized or depreciated against the product cost, it is a wise investment in the long run in so far as the combined operation can be carried out relatively cheaply, as often as may be necessary and, moreover, the plant can be arranged to rock or tumble the components, which is very important if even phosphate and lubrication coatings are to be produced.

It is found to be an advantage generally to commence cold extrusion from billets produced from hot-rolled bar. The reasons are as follows. Firstly the material is cheaper than turned or cold-rolled bar. Secondly the material is already in a condition where it will withstand a certain amount of cold work without an annealing operation. Thirdly, the first degree of cold work placed upon the billet can be arranged to size it to the die for the first major extrusion operation. Fourthly, the cold work done on the billet in this condition makes the material more susceptible to easy spheroidization in the subsequent sub-critical anneal, and material properly spheroidized is considered to extrude better than if this condition is not obtained.

The first preparation for cold extrusion is obviously the cutting of the billet from bar stock. This can be achieved by sawing, shearing or parting-off. All three operations can produce billets which are reasonably volumetrically constant and it is usually capital and existing plant conditions which determine the method to be followed. For automaticity, however, in feeding into the first press, it is obvious that billets must be free from rags. Also it is essential that billets are free from tears which can represent unsoundness in the extruded component. In certain shearing operations undesirable tears result particularly when using hot-rolled bar stock. Sawing and parting-off operations always leave a rag or an upstanding centre pip on the end of the billet. Furthermore, if the sawing feed or the set of the blades is too coarse, objectional markings on the billet surface results. Trials will establish the right sawing conditions and the operation can be quite cheap, as one operator can be required to operate a number of saws. The rags and saw-cut markings can always be eliminated to present no problem at all, if the billets are properly rumbled before the first sizing operation. If the upstanding centre pip which occurs in parting-off is reasonably small, it does not present a problem in the extrusion operation as the centre portion of the billet surface does not laterally extrude very far. It can, however, be a nuisance in automatic feeding.

First press operation (*fig.* 1) This can be called the 'dumping' operation. It follows the cutting and preparation of the billet and consists of squaring up the billet, dimpling and increasing the outside diameter to a size to suit free access into the first extrusion die. As has been stated, this can be carried out without annealing and usually without lubrication on billets from hot-rolled bar stock.

The operation is useful in that it takes account of the variation in bar diameter due to the hot-rolling tolerance. It also corrects the inaccuracies inherent in sawing and shearing and establishes two dimensions *A* and *B*, as well as effecting a reasonable dimple in the top or, if the tools are reversed, the bottom face. At the same time the opposing faces of the billet are made parallel with each other and truly perpendicular to the die axis. The variation in material volume in the billets would be arranged to come at the top of the side walls and, if essential, components at this stage can be high-speed machined to length *L*. If necessary, an alternative base form can be produced, as shown, which will probably assist at some later operation.

The prepared billet must now be annealed, pickled, phosphated and lubricated before the main extrusion operation takes place and, as these processing operations are usually repeated without variation between any two extrusions or draw operations, a full description of the process is necessary.

Annealing This is usually carried out without the use of protective atmosphere at a temperature just below the lower critical. Thus, for ordinary low-carbon steels the annealing temperature would be about 700°C. The annealing time can be important. On a billet of about $1\frac{1}{4}$ in. dia., $\frac{3}{4}$ h. anneal is sufficient to recrystallize after cold work and to give a certain degree of spheroidization. Full spheroidization is not considered absolutely essential for steels of the 0·2% C range and below. However, if extrusion is to be carried out on a 0·3% C steel, greater spheroidization is considered necessary and an annealing time of up to 4 h. may be considered necessary. It is important to achieve the greatest degree of softening and if it is convenient to leave a batch of work in the furnace overnight, then furnace cooling should be resorted to. Quick cooling, of course, must always be avoided. Controlled atmospheres are obviously an advantage in reducing the amount of scaling which occurs, but this is not essential and has never been carried out in the work done by the author to date. The hardness of the billet after annealing is normally about 120 V.P.N. for a 0·2% C steel and

135 V.P.N. for a 0·3% C steel and this is considered suitable for normal extrusions.

Pickling This is usually carried out in a 10–15% V/V* sulphuric acid solution with an inhibitor as a prevention against hydrogen embrittlement and also to obtain an evenly pickled surface. The inhibitor used by the author is Rodine III at a ½% W/V* concentration. The temperature of the pickling solution is always 70°C. and the time of immersion is normally 10 min. In the pickling and subsequent processing operations it is important to rock or tumble the components in order to reduce as far as possible the chance of certain areas of surface being improperly treated.

Rinse after pickling This is a cold running water rinse. Time of immersion is usually 10 min.

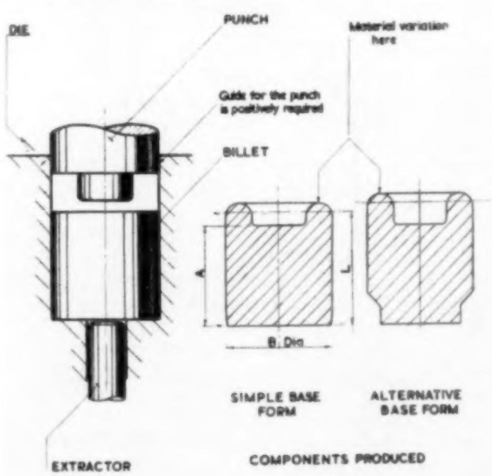
Phosphating It has been found in practice that a phosphate coating weight of about 2,000 mg./sq. ft.

*** Dilution terminology V/V and W/V**

V/V (volume by volume). *X* volumes of *A* are mixed with *Y* volumes of *B*. The unit of volume must be the same in both cases. An example being, say, a 6% V/V solution of alcohol in water. Take 6 gal. of alcohol and make up to 100 gal. with water, *i.e.* add 94 gal.

W/V (weight by volume). Indicates a difference in units, both weight and volume being employed. Typical examples being g./l., lb./gal., oz./gal., lb./100 gal., etc. A 6% W/V solution of salt in water would consist of 6 lb. of salt made up to 100 lb. with water, *i.e.* add 94 lb. It is not normal to weigh water, so convert the weight to volume, *i.e.* gallons. As the specific gravity of water is 1, and 1 gal. weighs 10 lb., the volume would be 94/10 or 9·4 gal. of water.

Similarly, the volumes of other liquids are calculated from their individual specific gravities.



TOOL SET-UP

1 *First press operation—dumping*

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Dusting with such a powdered lubricant, however, introduces complications firstly in the application and, secondly, in the loading of the die, which is caused by a coating of this lubricant packing solidly on the die bottom.

Second press operation—backward extrusion (*fig.* 2) This follows as the next press operation after dumping. The degree of cross-sectional area reduction is important in the maintenance of continued runs. The most heavily loaded tool is the punch and with a 50% cross-sectional area reduction, punch loading is of the order of 120 tons/sq. in. (plus). Loading curves show that the extrusion pressure is almost immediately employed which slightly increases as extrusion proceeds. The extrusion should not proceed beyond a base thickness ($T1$) which is equal to the wall thickness (T) otherwise shear effects occur in the side wall-base junction and punch loading increases considerably. However, a thinner base can be achieved over part of the base area by arranging for an upstand in the die-pad.

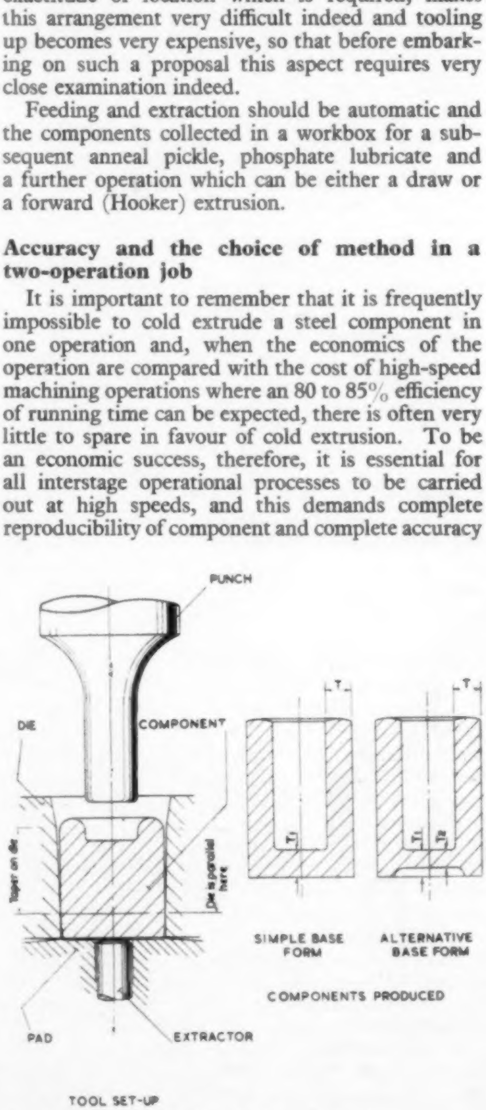
As extrusion load comes on to the tooling the effect is as follows. The punch swells slightly and evidence seems to indicate that more swell occurs at the first $\frac{1}{4}$ in. of length from the nose. The die expands elastically at the mouth and as extrusion proceeds the mouth diameter tends to recover its original diameter while the die is forced to expand lower down. If this effect is considered at near the end of extrusion it will be observed that, with a parallel die, the wall thickness of the extruded component near the base is greater than the annulus between the recovered mouth of the die and the punch shank. This gives a choke effect which increases the load on the punch and is therefore to be avoided, if possible, by tapering the die, allowing the mouth diameter to be larger than the base diameter. Because of this effect it is unlikely that perfectly parallel components are produced. It is seen that the die expands under load and the component produced is, therefore, larger in diameter than the die at rest. As soon as the extrusion load is released, therefore, the component is firmly held in the die. The punch recovers also and is usually free to withdraw from the cavity. The component is, therefore, left in the die and has to be extracted by means of an extraction bolster operating through the pad.

The length of the punch is very important in all backward extrusion operations, due to the column effect, which causes the punch to bend. If the punch is not centrally disposed and as near normal to the axis of the die as ingenuity can devise, the bending effect is more pronounced. For this reason, therefore, the effective punch length causing extrusion should not be greater than two and a half to three times the diameter of the punch. It is claimed by some experts that central guiding of the punch by means of a guide collar which is a very close fit on the punch, the working allowance being of the order of 0·0002–0·0007 in., permits accurate backward extrusion up to five times the diameter. The experience of the author, so far, is that the mechanics of locating the loose collar with the die, in order to maintain absolute exactitude of location which is required, makes this arrangement very difficult indeed and tooling up becomes very expensive, so that before embarking on such a proposal this aspect requires very close examination indeed.

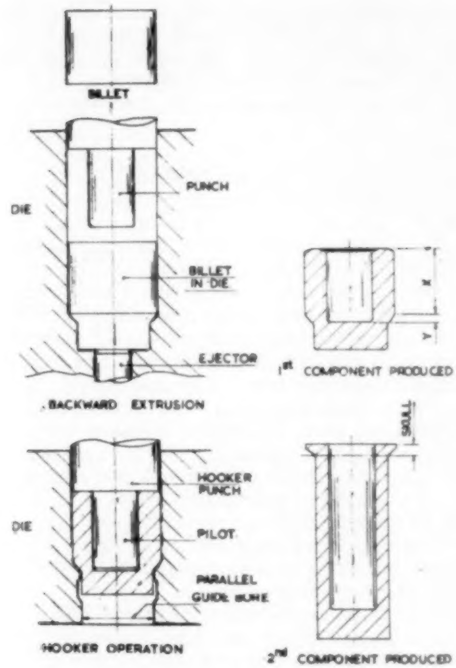
Feeding and extraction should be automatic and the components collected in a workbox for a subsequent anneal pickle, phosphate lubricate and a further operation which can be either a draw or a forward (Hooker) extrusion.

Accuracy and the choice of method in a two-operation job

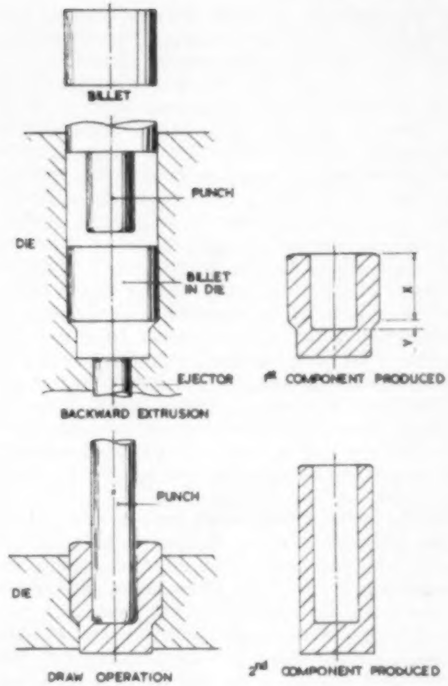
It is important to remember that it is frequently impossible to cold extrude a steel component in one operation and, when the economics of the operation are compared with the cost of high-speed machining operations where an 80 to 85% efficiency of running time can be expected, there is often very little to spare in favour of cold extrusion. To be an economic success, therefore, it is essential for all interstage operational processes to be carried out at high speeds, and this demands complete reproducibility of component and complete accuracy



2 *Second press operation—backward extrusion*



3 *Method* 1



4 *Method* 2

of relationship between one operation and another. A simple example to consider is that of a long closed-ended cylinder which is too long to extrude in one operation due to the fact that a long punch will tend either to wander or to bend. After the preliminary dumping which would be carried out as already described, such a component would possibly be produced in two main press operations, *viz*. either

Method 1 (*fig*. 3) (*a*) Backward extrusion operation followed by (*b*) forward (Hooker) extrusion operation, or

Method 2 (*fig*. 4) (*a*) Backward extrusion followed by (*b*) draw operation.

At first glance Method 2 would be favoured because of the fact that the draw operation succeeds in drawing all the metal into the wall, whereas the Hooker operation always leaves a skull of metal which has to be wasted, but this may not be practicable. The two methods referred to are illustrated in the accompanying figures. Unless there is a continuance of the initial and complete accuracy demanded from the first setting, very inaccurate components will be produced which cannot be salvaged. Accuracy must, therefore, be insisted upon at all stages from the preparation of the billet which must be volumetrically reproducible within very close limits and through all interstage operations.

Such accuracy as is required, however, can never be obtained if the press is not accurate in itself under extrusion loads. Experience to date leads to a very serious doubt as to the accuracy of presses even under static conditions and has made it necessary to line up presses to as near perfection as possible before permitting any tools to be mounted. Any inaccuracy in alignment of punch with die will cause a punch hardened up to 65–67 R.c. to shatter and this effect may force designers to use a softer punch with consequent lower tool life. If the backward-extrusion punch is not accurately centred in the die, the wall thickness will not be constant and this cannot be corrected by the subsequent draw or Hooker operation. If the depth of backward extrusion varies, the proper location of the component produced in relationship to the punch and die in the subsequent operation is not maintained and this very often results in undesirable effects such as overstrain on the metal. It must be accepted that billets cannot always be exactly the same volumetrically and allowance must be made for this in the design of

the first operation. A decision has to be made as to whether the top or the bottom of the component produced in this operation may be allowed to vary. It is usually found that the dimensions *X–Y* are very important and should be maintained.

A decision has also to be made as to whether the annular surface on the top of the component has to be accurately tooled or the thickness through the base. If Method 2 is used, which requires a 'draw' operation to follow the backward extrusion, it would appear that the base thickness would be most important, as the operation of backward extrusion can eliminate any further machining of the base. After the draw operation it then becomes only necessary to trim the mouth to a specified length. If Method 1 is used, however, it is important to accurately tool the annular surface at the top of the component. If this is not done the Hooker operation which follows the backward extrusion will not be balanced and the component will be bent notwithstanding the parallel guide-bore which follows the extrusion die. Considerable accuracy in the formation of the working surface of the extrusion die for a Hooker operation is also required if this undesirable effect of bent components is to be avoided. These undesirable effects do not occur to anything like the same degree in a 'draw' operation, as the inaccuracies are allowed to go free into the side-wall length. For this reason also, as well as the fact that a draw-die is much simpler and cheaper to produce, a draw operation as per Method 2 is normally favoured.

Plant costs

In carrying out an assessment of the economics of the cold-extrusion process the question of plant costs looms as a very important factor. Special consideration must be given to the press design, which must be robust to an unusual degree.

Once purchased, a press must be capable of being employed on many different types of operations and therefore the press characteristics must be sized on a generous scale both as regards physical size and tonnage. The speed of operation is of very great importance as it is obviously more economical to pay £40,000 for a press operating at 15 strokes/min. than £30,000 for a press operating at eight strokes/min. Presses are, in any case, so expensive in first costs, that very large outputs are required in order to have a reasonable amortization or depreciation rate per component. A press working at 15 strokes/min., however, will produce 31,680 components in a 44-h. week if working at 80% efficiency, and few concerns have orders to place of this magnitude. If a 15-strokes/min. press is purchased, therefore, complete sub-press tool sets should be designed which can be removed and replaced by another such tool set for a different component inside an hour. It may be argued that the figure of £40,000 for such a press is higher than present-day prices. However, the following typical characteristics should be borne in mind:

Daylight (stroke down)	5 ft.
Bed area	5 × 4·5 ft.
Tonnage	500
Deflection of bed under maximum central load limited to	0·002 in.
Stroke	20 in.

Bottom extraction		*Top extraction*	
Stroke ..	12 in. min.	Stroke ..	8 in.
Power ..	100 tons	Power ..	50 tons

A mechanical press of this type should be of the double-geared eccentric-operated type or have two crankshafts in order to balance the application of load over the ram area. The ram should be of very deep construction and very accurate guiding must be a feature. Lineability of the ram platen with the press bed should be very accurate indeed and no more than 0·001 in. out of parallelism over the whole bed area should be allowed. With a press to these characteristics a sub-tool press set with automatic indexing can be designed which will fit accurately and easily into position permitting quick changing of tool sets.

Such a sub-press tool set incorporating six stations in itself would cost about £4,000 and such a tool set could be expected to carry out all cold working operations required including drawing to an approximate finished length of 10 in. In a six-station automatic tool set, two feeding stations, two backward extrusions and two draws could be accommodated so that a duplicate of a three-operational tool set could be provided and double the number of components produced per unit of time.

If all six stations are to be employed to produce one component it is clear that four extrusion stations are being employed. That being the case, very careful sequence of operations will have to be planned in order to take account of the maximum workability of the steel. In this connection, reference is made to the peculiarities of preferential extrusion of the material occurring in a simple backward extrusion from which it will be noted that the base surface and areas local thereto extrude the least in this operation, whereas areas of the top surface which subsequently form the cavity extrude the most. It will be quite clear to all readers that unless the whole of the six stations are fully employed there is wasted effort by the press. The accuracy of guiding required in the ram of such a press is obvious from the fact that six stations will be employed and there will be some unequal loading and consequently preferential straining of the ram face.

The preference for a mechanical or hydraulic

press is probably vested in a number of considerations. The following are worthy of note: the number of strokes per minute, power required, the type of operation to be carried out and plant cost. Hydraulic presses may be considered as being kinder to the tools and particularly to the punch in the long run. The crank angle effect of a mechanical press after some time in use, when the gudgeon bushes and eccentric sheaves are showing signs of wear, can be disastrous to a punch which is already locked in a component in so far as the throw-over of the ram against the gibs effects a bending movement on a punch locked at each end. For that reason, therefore, the adverse press effects which can be present in a mechanical press after some years of use should be eliminated by making the sub-tool press sets complete in themselves and most rigidly guided.

Having discussed the main press at some length and reasoned regarding its cost of £40,000 plus £4,000 for tooling, attention can now be given to the other equipment required.

Saws Based upon 3–4 min. operational time and 80% efficiency, 12 saws would be required which would represent a capital investment of about £10,000.

Rumblers About four rumblers valued at £2,000 would be needed.

The weight of material handled per hour assuming billets 1½ in. dia. by 2½ in. long is about 1,820 lb.

Furnace A suitable furnace to anneal these up to a maximum of 750°C. would cost something like £18,000.

Pickling, rinsing, phosphating and lubricating plant An automatic plant for this incorporating tumbling barrels would cost about £10,000.

Total plant costs

	£
Twelve saws or one shearing press ..	10,000
Four rumblers	2,000
One furnace	18,000
One processing plant	10,000
One press for dumping with automatic feeding gear	12,000
One extrusion press	40,000
One sub-press tool set	4,000
	£96,000

Plant amortized over eight years at 60% efficiency, 48-week year—plant amortization works out at 3·10d./component.

Punch material

Realizing that the success of any cold extrusion process lies very largely in the life of the punch, the first material employed by the author was high-speed steel because of the high compressive loads which it can be expected to withstand. It was found, however, at that time that punches in H.S.S. of the high-tungsten type could not be relied upon and they frequently shattered. It is not certain, at this stage, how much this adverse effect was due to inaccurate lineability as, since that time, various inaccuracies have been found in the presses employed and in large measure these have now been corrected. Even so, failures still occur in the early life of the punch and have been attributed mostly to inaccurate setting up in the first trials. As a result it is now standard practice to use setting masters as a gauge to the accuracy of initial tool setting. The failure of H.S.S. punches, however, turned attention to the use of alternative steels and production continued with the use of 2% C, 12% Cr steel, the characteristics of which are included hereunder. Punch life, however, is still variable, although much longer runs of up to 8,000 components/punch were being obtained.

Nominal composition: 2% C, 13% Cr. Other elements are not normally specified or published but would be in the order of 1% each Si, Mn and Ni. S and P would be approximately 0·030% each.

Hardening Usually by oil quenching from 950–980°C. after slow preheating first to 700–750°C. to avoid thermal shock.

Small sections will air harden (up to about 1 in. dia.), but in this case it is usual to increase the hardening temperature to about 1,000°C.

Water or brine quenching would result in: (*a*) Severe cracking; (*b*) a marked reduction in hardness

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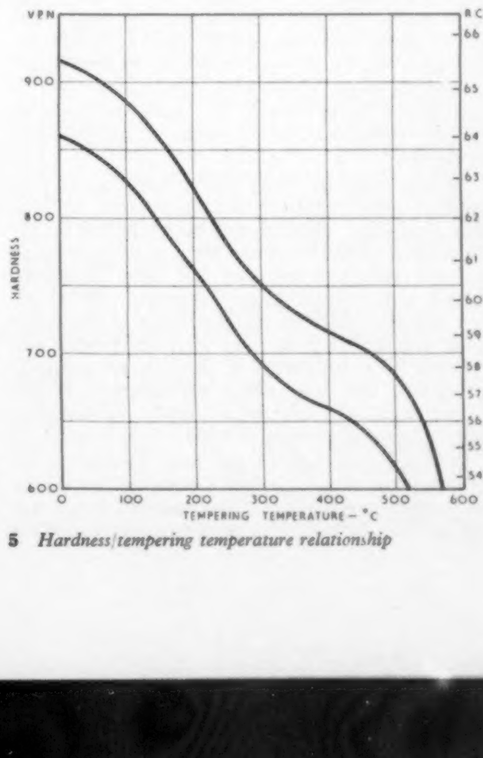


5 *Hardness/tempering temperature relationship*

LETTERS *to the Editor*

Metallurgical education

SIR: The unusual manner in which the Institution of Metallurgists has introduced a revision of its metallurgical education scheme, referred to in a letter by A. D. Hopkins and in the editorial of the May, 1961, issue of METAL TREATMENT, has been received with some anxiety by many members of the profession.

The revisions have appeared, apparently, without any open criticism or comment during their preparation from a sufficiently widely representative section of industrial and teaching metallurgists. Although a meeting to consider the revised syllabuses has now been suggested for November, 1961, by this time the first-year courses of the new scheme for the L.I.M. will be well under way in most colleges. It would seem unlikely, anyway, that any fruitful modifications will be forthcoming from such a limited assemblage of opinions, *unless* directed by a clear statement, from a fully informed, authoritative and representative body, as to what are the objectives and policy for present-day, national metallurgical education.

The last report of the Joint Committee on Metallurgical Education appeared nine years ago. It is not improbable, therefore, that conditions have sufficiently changed to warrant a further revision of the committee's recommendations. For example, in 1952 one of the conclusions in their report was that: 'Nothing has emerged from the present survey to shake the committee's opinion that the universities are the chief source of high-grade metallurgical technologists, and it doubts whether any other source of equal value can be developed' (para. 58, page 52)—surely a statement that is continually being refuted by many industrialists and by those engaged in advanced technological education.

At the present time, the overall pattern of national metallurgical education appears jumbled and confused. This has not been clarified by the Institution of Metallurgists' attempt to produce an ordered system which has not been developed from a wide enough range of opinions. No extensive research has been recently made to determine what industry requires, and what universities and colleges of technology can offer in metallurgical education, that will equip metallurgists of the future with the ability to apply fundamental principles to the solution of practical problems.

Why not now reform the Joint Committee on Metallurgical Education with a wider representation of teaching and industrial metallurgists? Its task should then be two-fold, to determine: (1) What academic and practical knowledge is required by various industries from a newly-trained metallurgist, (2) how may technical colleges and universities best equip their respective students with that knowledge; especially taking into consideration all the possibilities of specialization for particular industrial regions. Only when this information is available will any attempt to revise metallurgical education syllabuses be practicable along constructive, purposeful lines.

R. ROLLS

The Manchester College of Science and Technology
Department of Chemical Engineering, Fuel
Technology and Metallurgy
October 2, 1961.

Cold extrusion of steel

concluded from page 399

due to retained austenite. Some of the austenite would be transformed on tempering, but the overall effect would be to give a very much flatter curve than that below but at a lower level commencing at 50–55 R.c. in the hardened condition.

Tempering Hardness/tempering temperature relationships are given in fig. 5, which shows the range of hardness to be expected.

Temper to obtain a hardness of 750 V.P.N.

In the meantime, certain high-silicon steels were designed and patented and the first punch in this type of steel yielded 12,000 components before the punch failed due to wear on the nose. Meantime, Cu-Si-Mo-V steels have been developed which show interesting and more superior characteristics. It was intended to carry out further development work on these steels but fortune, in the way of further trials using 5% Mo H.S.S., yielded such considerably improved results that further work on other steels was discontinued. After further truing up of the tool set, it was found that the 5% Mo H.S.S. punches produced 60,000 components before failure.

Attention has also been given to the manufacture of tungsten carbide punches, and certain designs are in the process of manufacture. Very considerable benefit can be derived from the successful use of tungsten carbide, not only because of the increased wear characteristics, but also because its Young's modulus is so much higher. Longer extrusions should be possible because the column effect upon the punch will be reduced. These developments have not so far been concluded.

to be continued

Explosive forming

The following notes summarize some recent American experience in the shaping of complex parts and difficult materials by explosive forming. As well as discussing forming by means of the detonating type of charge, a related technique relying on a combustible gas mixture is described. This technique, whilst still giving high forming rates, is much more controllable than high explosives, and has the added advantage of presenting less difficulty in siting

MANY DEVELOPMENT PROGRAMMES have been conducted to evaluate explosive forming, and the results have provided data which permit design engineers to consider it as a useful production process. At Ryan Aeronautical Co.,* for example, 47 different types of shapes or configurations in numbers ranging from 25 to as high as 1,000 parts have been produced. In both production and development a total of 250 configurations have been formed.

The success of explosive forming stems from these principal advantages:

(1) The size of explosively formed parts is not restricted by present facilities and equipment, but by other factors such as the size of dies and available sheet and the ability to handle the die and the material.

(2) Sufficient pressure and capacity for forming the strongest of our new superalloys is available through explosive forming.

(3) Explosive forming utilizes speeds up to hundreds of feet per second compared to conventional machines which form metals at speeds up to 5 ft./sec. The use of high- and low-pressure explosives can be varied to regulate the forming speed.

(4) Parts have been consistently produced to within 0·001 to 0·002 in. of the die because there is no spring-back. Of the hundreds of dies made for this technique, not one has been machined to allow for spring-back.

(5) On most explosive-formed configurations, thinning is no problem. When forming is severe, it can usually be accomplished by a combination of explosive forming and chemical milling.

Design engineers may find this new technique particularly valuable for forming unusual bulges and shapes not readily formed by other means, for combining several parts into one piece, where a combination of explosive forming and heat treating would be required to get the desired yield strengths, and in making parts which would be impossible and impractical to form with a die and punch.

Designing for explosive forming†

In the early stages of explosive forming its most important use was in production of parts which were very difficult or expensive to form by conventional methods. Although the large forces attainable with explosives give the method a definite advantage in forming some parts of this type, the greatest advantages lie in making parts specifically designed for explosive forming. There is, for example, no advantage in explosive forming for long production runs or parts which are designed for and easily formed on conventional equipment. However, it may be used to form a completed assembly in place of a number of subassemblies; here it shows definite economic advantage.

A major consideration in designing for explosive forming is the characteristics of the material from which the part is to be made. Some knowledge of the relative formability of each new alloy—compared to some basic metal—is a great aid when considering the potential of explosive forming for making a part. Data of this kind are not intended to indicate what metals can and cannot be explosively formed; they do, however, shed some light on the relative weight of explosive charge required for various materials.

Probably the most important item for the designer who is considering explosive forming is the explosive charge. The explosive is merely a source of energy—the same as supplied by any forming machine. However, because of their nature, explosives provide a highly concentrated source of energy. For example, a 2-oz. charge will do the work of a 10-ton press on a small part, and the

* F. A. Cox, Manager, Mfg. Research & Development, Ryan Aerospace, Div. of Ryan Aeronautical Co., San Diego, Calif. *Metal Progress*, August, 1961.

† V. H. Monteil, Research Department, Rocketdyne, Div. of North American Aviation Inc., Canoga Park, Calif. *Metal Progress*, August, 1961.

work of a 40-ton press on a part twice as large. Furthermore, explosives can be put into a very small space (as small as 0·1-in. inside diameter) to accomplish this work. The explosive may be placed in almost any position to form the part as desired.

In its present state of development the forming cycle for explosive forming is usually longer than that required on conventional machines, particularly for long production runs of small, simple parts. However, as the number of parts decreases and the size increases, the cost of explosive forming remains nearly constant while the cost per part for conventional forming goes up appreciably. This is especially true for parts requiring matched male and female dies for conventional forming. Only a single female die is required in the explosive technique.

For normal explosive forming operations the ordinary limits of material elongation and minimum bend radii may be used as a rule of thumb. Material thinning is generally similar to that obtained during conventional forming except that more control is possible. Quite often it is possible to gather material or to apply a more uniform load to a workpiece during explosive forming. Thus, thinning of a deep part can be reduced and sections of nearly uniform thickness can be made.

Ordinary tolerances for explosive forming are of the order of $\pm 1/32$ in. Such parts can be formed quite rapidly and easily. Close tolerances down to $\pm 0 \cdot 001$ in. are also easily obtained, but a longer forming cycle and better dies are needed.

Explosive forming with combustible gas mixtures

In forming with explosive gas mixtures, the detonating type of explosive charge is replaced with a mixture of combustible gas and oxygen. The die is completely sealed, the combustible mixture is then fired, and the part is formed by the resulting pressure build-up.

Work on this method of forming began at Boeing Airplane Co. early in 1960;‡ it is aimed at overcoming some of the limitations of conventional explosive forming in which solid explosives are used. For example, some materials and shapes, particularly in the thin gauges, present a forming problem when detonating types of explosives are employed. Part fracture can occur unless forming is done with a small amount of explosive, or unless the explosive charge is moved away from the workpiece. Conversely, if the amount of the explosive is too small, it may not fire, and if the charge is too far away, it is difficult to obtain uniform forming pressures. A technique is required which provides lower forming rates and pressures that can be better controlled than high explosives; it must, however, retain the advantage of rapid forming rates. The use of combustible gas mixtures appears to be a solution to the problem because the forming rates which result are still high compared to those encountered in conventional forming, but are less than those produced by detonating explosives.

Advantages of explosive gases Combustible gas mixtures have several apparent advantages. For one thing, the gas fills the cavity and provides intimate contact with the workpiece. This is an ideal shape for a charge. The die chamber can be quickly recharged and fired. In addition to slower burning rates than obtained from detonating-type explosives, gas mixtures give more uniform forming pressures. The pressure peak is sustained longer and a much wider range of pressure control is feasible. Gas volume, the mixture ratio, and the initial pressure can be easily controlled, and the combination of Boyle's and Gay-Lussac's or Charles' law ($PV/T = P'V'/T'$) provides a simple theoretical means for relating the important factors. In the system chosen for development, the gas volume, the initial pressure and ratio of gases can be varied. A mixture of hydrogen, oxygen and an inert gas serves as the explosive.

Experiments at Boeing At Boeing, combustible gas mixtures have been employed for both sizing and forming operations. Charge volumes ranging from ¼ to 70 cu. ft. and starting pressures from 1 atmosphere to 14 atmospheres have been used. Initially, the effects of mixture ratio and pressures were investigated by free forming 10-in. dia. domes in a standard die. Later, dies previously used for high-explosive forming by the submerged process were adapted for use with combustible gas mixtures. Materials ranging from soft aluminium to high-strength alloys have been successfully formed.

According to present procedure the workpiece is placed in the die and a vacuum drawn between them. The volume to be occupied by the charge is then purged with an inert gas before introducing hydrogen and oxygen. Although many mixture ratios are being presently tested, they have been consistently hydrogen-rich to minimize oxidation. In some instances, an inert gas has been mixed with the hydrogen and oxygen to dampen the charge and further refine our control of pressure. Two methods are currently being used to fire the charge—an electric spark or a glow plug. It now appears feasible that forming operations can be moved indoors and performed above ground. This compares with forming with high explosives which must be done at remote areas in a water pit.

‡ J. Miller, lead engineer of the explosive forming group, and P. Kruse, lead engineer of the advanced projects group of the Boeing Co., Seattle, Wash. *Metal Progress*, August, 1961.

Costing heat-treatment operations

E. P. WILSON, F.A.C.C.A.

The importance of realistic cost ascertainment when fixing selling prices is unquestioned in most industries. In this article, contemporary ideas of costing are described in the context of heat-treatment processes, and it is shown how they help to provide a realistic basis for fixing selling prices when taken in conjunction with the experience of the technical staff*

THE AUTHOR'S background to the subject of heat-treatment costing has been provided by the heat-treatment installations belonging to the West Midlands Gas Board at Birmingham and Coventry, and to a lesser extent by war-time experience on accounting investigations carried out for government departments at very many engineering firms of all types. The heat-treatment shops of the Gas Board are there to give advice and also to provide a processing service which now extends to industry far beyond the boundary of the West Midlands Board. They are also there to promote the sale of gas. That does not mean that the Board does not care whether the plant is profitable or not. It has to earn its keep regardless of the fact that heat-treatment revenue is only a small percentage of the Board's total revenue.

Gas for industrial purposes is important for any Gas Board. It is of vital importance to the West Midlands Gas Board, for over half of the total gas sold in this area goes to industry and, of this portion, heat treatment is quite a substantial factor.

Historical considerations of accountancy

The practice of double-entry book-keeping was developed in Italy in the Middle Ages, mainly as the result of the commercial stimulus of the Renaissance, but was not used in this country until later. It was the Industrial Revolution of the last century which saw great strides made in book-keeping methods, but even in the early years of this century the accountant rarely stepped outside his profit and loss account and balance sheet. Indeed, in my own day as a student, I met many diehards who looked upon the rapidly developing cost accounting as sheer nonsense.

If accountants were to serve industry in the difficult years of the thirties it was clear that such prejudices had to be swept away, and so budgetary control, and then standard costs, were evolved, more as the result of accounting research in this country than in America, although the idea caught on more rapidly there.

The second world war and the Government's insistence on costing and investigating war-time contracts gave added impetus to the introduction of improved techniques, sometimes under the now familiar title of management accounting. This does not mean that there has been a departure from the basic principle of double entry, but is rather a recognition that accountants have a far greater service to give at all levels of management than merely to balance the books, however important that may be.

In these days, management expects to be given results quickly. Up-to-date assessments of the financial position are required not several weeks or months after the close of the financial year, but at much more frequent intervals, even though approximations may have to be used.

In the early days of cost accounting the main idea was to present management with the total cost of each job or each process. It then came to be realized that these figures were of limited value unless they could be compared. The answer was to set up a predetermined cost based upon normal operating conditions, and keep management informed of the variations from these forecasts or standards. This has the advantage of avoiding re-examination of basic costs (some of which will be fixed in any case) and of spot lighting the variances which are more subject to the controlling influence of the supervisory staff.

When we turn to heat treatment it must be admitted that accountants seem to have been shy

*Article based on the lecture given by the author at the Birmingham College of Advanced Technology last January in the series 'Modern developments in the theory and practice of steel heat treatment.' The author is Divisional Accountant of the Birmingham Division of the West Midlands Gas Board.

in introducing contemporary ideas, and during my few years on contract cost investigations I rarely came across anything other than rule-of-thumb methods. It is my impression that in many cases there is a groping for what is, in effect, a standard. There seems to be more than ordinary interest shown in quotations from other firms, and I suspect that there are times when quotes are obtained from other heat-treatment firms, not so much with the idea of giving the work out, but to find out whether an estimated price is reasonable.

In most products the accountant has a great deal to say in price fixing, but when it comes to the heat-treatment industry it is somewhat different. My own association with heat-treatment staff has been a happy one, but I have visited firms where some resistance existed towards the offer of more accounting information, and where figures which had been provided were distrusted. It seems at least reasonable to suggest that there is scope for more co-operation.

At this stage cost ascertainment must be distinguished from the pricing of work for invoicing. This sets two main tasks. First to discuss the elements of cost, and secondly to apply the costs to selling price.

Cost per furnace hour

The object is to arrange costs so as to arrive at the cost per furnace hour. This is a figure which should be known, although it does not follow that all pricing should entirely depend on it.

Starting with the plant, it is necessary first of all to group the furnaces. With very large modern furnaces there may be justification for taking individual cost. The grouping of the other furnaces may be simply between large and small. It is, of course, a question to be determined for any particular installation. If the groups are too numerous some allocations of cost may be trivial, on the other hand, if the groups are too large, some classes of work may be done at an undisclosed loss.

The direct factor of cost, such as power, can generally be metered and presents little difficulty. It is another matter when maintenance has to be considered. I have been impressed when speaking to the supervisory staff at Adderley Street by the difficulties that occur with work which damages the furnace linings. In accounting for the manufacture of gas, it is the practice to put a sum aside for every ton of coal carbonized, and so set up a fund against which the cost of resetting the retorts is charged. This form of equalization of charge works well, and I see no reason why, by adopting this principle, every furnace hour should not bear a proportion of repair charge. Over a period of a few years, it will be seen whether the fund is adequate or not, and adjustments of the charge may be necessary from time to time. Historical costs provide the only real basis for arriving at an equalized charge unless the plant is of an entirely new type.

The task of assessing charges for items such as boxes and pans which are used over a short period, or are in constant repair, can raise special difficulties when pans which are new take a greater number of units than when they are warped. Those firms with a regular flow of work of their own manufacture can equalize this without much difficulty, but where it is that a heat-treatment service is provided it may be desirable to leave the charge out of the furnace hour rate and charge the class of work which demands boxes and pans. In practice this cost may not be sufficient to warrant special treatment, but at Adderley Street the expense is too large to be treated lightly, and an equalized charge is made for every accounting period.

For day-to-day maintenance there must obviously be a regular charge, and this brings us to the question of labour. In heat-treatment operations it is the furnace which requires the time card and not the man. The man's time can be endorsed on the furnace card if it is necessary to record it at all for costing. There will be inequalities in that labour may be spent loading and unloading heavy material, but unless this is exceptional it need not be taken into account. It is probable that cranes would have to be allocated to the larger furnace groups. For instance, it would be inequitable to load this charge on to, say, a cyanide furnace.

Overhead charges

On the question of overhead charges, managements generally, and I am not thinking of the gas industry, give less attention to this aspect of cost than it deserves. When arranging costs to provide a unit such as cost per furnace hour, the importance of overhead charges may not be fully realized.

For the moment, let us consider production engineering. Of the various elements of cost, overhead charges are often greater than either labour or material. It is the practice in very many firms to recover overhead charges as a percentage on labour, and the rates used vary anything between 350–700%.

In these days, items such as National Insurance, sick pay, holiday pay and canteens, form a substantial element of cost before adding supervisory, clerical and headquarters charges. There must then be added an appropriation of rates, gas, water and electricity, telephone, stationery and printing, insurance, cleaning and all the items that cloak themselves under the heading 'sundry.' Then there are salaries and administrative charges, before

we come to a matter that is extremely controversial —depreciation. This is a subject which requires some consideration.

Depreciation

A decision has to be made between two major principles—whether to provide depreciation to replace the original cost of the plant or whether to provide for the cost of replacement at present-day values. For my own part, I would prefer the first, that is the historical cost basis, and there is much to be said for writing this off each year on the straight-line method. By this method, if a unit of plant costs £1,000, and its life is estimated at 10 years, then the charge would be £100 each year. It is true that textbooks contain seven or eight other methods of charging depreciation, but for simplicity there is nothing to better the straight-line method, and many of the arguments in favour of the others break down in practice.

We must not ignore, however, the question of replacement value. Since the second world war there has been an almost constant upward trend in prices and there are many who believe that a provision for depreciation which is based on original cost is inadequate. It is maintained that present-day costs can only be properly assessed if they include a charge for depreciation that is calculated to cover the cost of replacing the plant on a higher price level than the original.

It is also argued that costs based on historical depreciation will increase when replacements are made because of the increase in the depreciation charge and, if this is heavy, it may not be possible to justify increases in selling prices which were based on earlier costs. There is a compromise which some accountants adopt when using the historical basis for the financial accounts but take the replacement basis for the purposes of internal costing.

There is yet another school of thought which gets over the problem by revaluing assets at frequent intervals and constantly adjusting the depreciation charge.

If it is decided to depreciate on a replacement basis, the difficulty with which one is at once confronted is 'What is replacement cost?' There is one trade association which advises its members to calculate replacement value on indices published by the *Economist*. These represent the approximate ratio of the current price of capital to the price of the same or similar equipment in 1937, which is taken as a basic year. By using these indices all additions to capital equipment since 1937 can be reduced to the 1937 level and depreciation re-calculated on that basis. Based on an index of 100 for 1937 the present index number is somewhere between 350 and 400.

Now management must make up its mind about this, as it is a management problem as much as an accounting one. One of the arguments, I feel, against the replacement basis is that in these days of rapid development plant is seldom replaced by that of a similar type. Developments are so rapid that replacement may take a very different form than at first envisaged. On balance, therefore, I am against replacement basis because it fails for uncertainty. At the same time the challenge of the times must be met and one must be prepared to regard plant as obsolete even well before the end of its useful life, and I strongly suggest that a development reserve should be created out of profit margins.

There is one further point worth making on the matter of depreciation. On the whole, the historical basis depreciation periods tend to be conservative, and if a unit is written off as though it would finish its useful life in, say, 10 years, it often lasts a few years longer. It is reasonable to continue the depreciation charge through the extended life and in this way a sum is being set aside for eventual replacement. Great care must be taken with depreciation charges as undue loading under this heading can be dangerous to a business, while, on the other hand, if adequate provision is not made the financing troubles may later be disastrous.

Setting up the budget

Having taken everything into account the productive furnace hours must be obtained, including charging, heating, cooling and emptying. Together with the furnace hours available in any account period, it is possible to arrive at furnace availability as follows:

$$\frac{\text{Furnace hours worked}}{\text{Furnace availability}} \times 100$$

By totalling all the charges it is clearly possible to divide by furnace hours worked to give the cost per furnace hour. Incidentally, I suggest a minimum of one month and a maximum of three months for the accounting periods. This allows provision for seasonal fluctuations. If the availability percentage moves upwards and the hours worked are likely to increase, an adjustment of the budget will have to be made. Some charges are fixed whatever the output, some will vary directly, or almost directly with the output, and some will vary indirectly. The classification of charges as to whether they are variable or not gives the budget the degree of flexibility necessary for efficient running.

It is during the formation of the budget that the opportunity occurs of looking at the detailed charges. Experience shows that it is this detailed analysis of every item of expense when first setting up budgets that finds the savings. As mentioned previously, overhead charges have a tendency to increase over the years and time spent on full review is nearly always rewarding, often to a surprising extent.

Fixing selling prices

We must now look at the problem of how this information is to be of assistance when charging out, whether to other departments of the same organization or to outside firms.

In 1948, having reached the point of establishing the furnace hour costs in groups, we were confronted with this problem of charging. There were the usual factors present of putting two jobs in the furnace at the same time, while having the furnace idle at other periods. The greatest single asset in all this is the experience of the heat-treatment supervisor. The only way we could be sure that the selling prices based on so much per lb. were making ends meet was to concentrate on a trial period—in this case four weeks. It must never be supposed that any accounting reform in a business can be put in overnight, and there is always a critical period finding out if the scheme works.

I must say that we relied very much on the experience of the technical staff to translate cost per furnace hour into pence per lb. for what I call 'bread-and-butter' jobs, when there was a direct relationship between weight and the ascertained hourly cost. The heat-treatment shops of the Gas Undertaking took on all classes of work. At the time of investigation the work included stainless-steel sinks and aluminium foil, and it was obvious that the basis of weight was not suitable for work of this type.

This leads to a mention of a practical snag which has to be overcome. It is necessary to know not so much the *invoiced* total to customers but the *selling value of the work actually done* in each accounting period. That is to say the time lag between doing the work and invoicing must be eliminated. This is a detail, but it is an important one.

It will soon be discovered whether the prices being charged are reasonable or not. In our case we found that one group of furnaces was subsidizing another, and so prices were adjusted. As the results were known very soon after the end of the accounting period, it was possible to make price amendments very quickly. Even so, it was a few months before the point was reached when each group of furnaces was on a sound basis. After an early period of concentration, the accounting side of heat treatment becomes mere routine, although the differential between the various furnace groups must always be watched.

While convinced of the difficulties involved in pricing heat-treatment services, it should be known clearly what proportion of work is steady and remunerative in what I have called the 'bread-and-butter' sense, taking a basic charge of, say, 1s. per lb. per hour. If this proportion of work is high, some risks can be taken on the fewer jobs which are difficult. From my limited experience, it seems to me that most installations are working under basic conditions for a great deal of time, and I am sure that those who have installations concerned only with their own manufactured products have much less difficulty than those who are providing a general service.

In the first place there must surely be a minimum price, say at 10s., 15s. or £1 to meet standing charges. Furthermore, the cost per furnace hour may not be sufficient when dealing with, say, Nimonic alloys which require only a few minutes' treatment in the furnace but incur a disproportionate amount of handling and supervisory attendance. The labour factor must be taken into account, and for this it may help to know the cost of a group of men for a fraction of an hour. To include shop overhead charges a rate of 100% on basic wages would give reasonable cover and is easy to apply.

When all is said and done the experience of the man on the spot is the greatest asset of all. If he takes a trial heat when dealing with difficult loads it is not often that anything more than marginal losses occur when he knows furnace hour costs. No business can run with a constant profit margin on everything undertaken.

I have not dwelt on the question of profit. The matter is delicate. There are firms who have admitted that, up to the war, they based their estimates on material charges, and they then assumed that wages and overhead charges taken together were equal to the material charges and that the profit margin should also be equal to the material charges. If they came out on what they called the 'right side' they were satisfied. But as to the ratio in which profit was earned over the various classes of work they were quite ignorant. Post-war developments and taxation have brought about a changed outlook.

Acknowledgments

In conclusion, I must express my thanks to the chairman of the West Midlands Gas Board for the facilities I have been given in preparing my notes and also to my colleagues for their help.

Investigation into the stability and accuracy of gauge blocks

The U.S. National Bureau of Standards has recently fabricated gauge blocks that are dimensionally considerably more stable than those commercially available today. Special measurement techniques to evaluate these gauge blocks have also been developed

IN A RESEARCH programme aimed at an accuracy of 1 part in 10 million in gauge block calibrations, the U.S. National Bureau of Standards has recently made significant advances with the development of highly stable blocks and ultra-precise measurement techniques. Three types of gauge blocks, produced by the Bureau's metallurgy laboratories, show dimensional stability considerably greater than the best commercial blocks made so far. To obtain precise data on the small dimensional changes occurring in the blocks, special measurement techniques have been devised.

Gauge blocks, carefully made of steel to exact dimensions, are used to minitor manufacturing processes in the mass production of interchangeable machined parts. As reference standards for such high-precision manufacturing operations as the making of machine tools, ball bearings and missile control mechanisms, gauge blocks must be capable of providing measurements precise to within 1 part in 100,000 or even, for some recent applications, to 1 part in 1 million. Therefore, as the length of a block must be known even more accurately than the measurement referred to it, gauge blocks certified to 1 or 2 parts in 10 million must soon be made available on a regular basis.

To meet these increasing demands for precision, the Bureau is focusing attention on the characteristics of the gauge blocks themselves as well as on the equipment and methods for measuring them. Because of the industrial importance of this work, a group of private firms is helping to support the metallurgical research underlying the fabrication of precision gauge blocks and the developmental metrology for achieving calibrations of the required accuracy.

Gauge block metallurgy

A special effort is being made to develop gauge blocks that will retain their calibrated lengths to high accuracy over a considerable period, with much less shrinkage than is normally expected of precision gauge blocks. At the same time, other requirements for gauge blocks cannot be neglected. These include an appropriate coefficient of thermal expansion, a high degree of surface finish, flatness of surface, parallelism of opposite gauging faces and resistance to wear, deformation, and atmospheric and fingerprint corrosion.

Dimensional instability in steel blocks is thought to result from structural changes in the hardened unstable structure formed during heat treatment and the subsequent redistribution and relaxation of fabrication stresses. Therefore, a properly fabricated block of fully annealed steel of low alloy content, at or near its equilibrium condition, should be free from subsequent structural changes. However, such a block is too soft to use as a gauge block because an adequate finish cannot be applied, wear is high, and the surface is easily deformed. An alternate approach is to lower residual stresses in hardened steels by stress relieving at around 540°C., but this process also makes most hardened steels too soft.

To produce a hard, wear-resisting surface on the annealed material, the Bureau nitrided steels, chromium plated some, coated others with either tungsten carbide or aluminium oxide, and sprayed still others with nickel-chromium-boron alloy. In attempts to improve the hardened steels, the Bureau tried to eliminate as many of the unstable constituents as possible, and to reduce fabrication stresses. Some blocks were case hardened on the surface by carbo-nitriding, carburizing, and cyanide hardening.

Sufficient data have been obtained on blocks of 410 stainless steel, and 52100 modified steel, to indicate that such methods can result in greatly improved stability. Annealed 410 stainless blocks with nitrided surfaces have been produced which exhibit a growth of only $0{\cdot}2 \times 10^{-6}$ in./in./yr. during the first year of observation, and 52100 steel gauge blocks, given special stabilizing and stress-relieving treatments, display a shrinkage of

$0{\cdot}4 \times 10^{-6}$ in./in./yr. At present, 16 materials (table 1) are under investigation and have been given a total of 42 different treatments (figs. 2-3).

TABLE 1 *Gauge block materials under study at NBS*

1010	D 2 tool steel
W 4 tool steel	Nitralloy 135 Mod
52100 Mod	17-4 PH stainless
8620	Titanium carbide A
304 stainless	Titanium carbide B
405 stainless	Titanium carbide, steel binder
410 stainless	T 15 Mod, tool steel
420 stainless	Aluminium oxide

Gauge block measurements

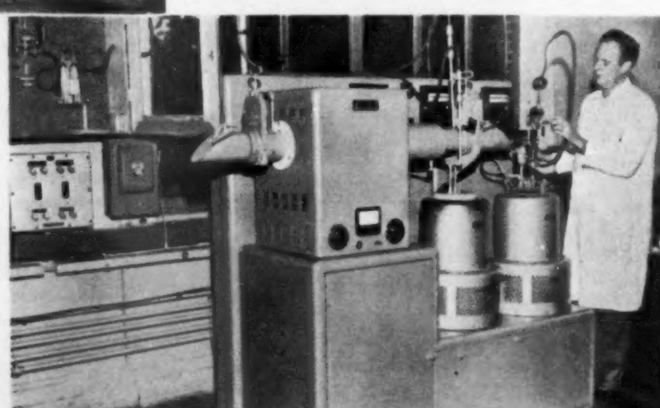
In evaluating the stability of gauge blocks, the Bureau employs two types of measurements: 'static' comparison which is carried out interferometrically and 'dynamic' comparison which relies on a mechanical-electronic technique. By exploiting the features of both comparison procedures, it is possible to detect the occurrence of very small dimensional changes and still conduct the large number of weekly measurements which are necessary.

Until recently, very precise length measurements were generally accomplished interferometrically. For such measurements, a Bureau-designed comparator is available which is capable of meeting the most rigorous of present accuracy requirements. In this device a test block is compared with an absolutely measured standard length—a steel gauge block of established stability with the same cross-sectional dimensions and nominal length (2 in.) as the test block.

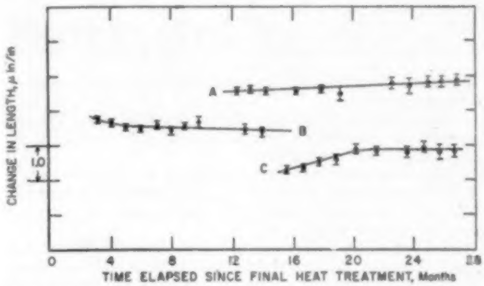
However, because comparisons of this type require that the two blocks be at thermal equilibrium, each test takes at least 4 h. As more than 50 measurements must be made each week, a more rapid technique that would allow measurements to be made immediately after handling was needed. Such a comparison, usually carried out with a mechanical comparator, is called 'dynamic' because both blocks are actually changing in length during the measurement as a result of changing thermal conditions. An accurate dynamic comparison can be made between blocks that respond similarly to thermal conditions if these conditions are the same for both blocks immediately prior to and during the measurement.

The mechanical comparator employed in the dynamic length comparisons, utilizes electromechanical transducers to indicate the position of two styluses. Gauge blocks are successively

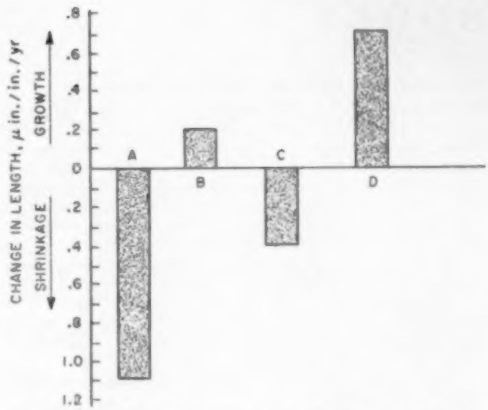
1 ABOVE *Neutral salt baths used to harden 52100 steel gauge blocks by immersion at 845°C. for 15 min.*



2 RIGHT *Nitriding 410 stainless blocks in an ammonia atmosphere for 40-44 hours at approx. 550°C.*



3 *Stabilities of:* (*A*) *nitrided* 410 *stainless steel;* (*B*) *hardened and stabilized* 52100 *steel;* (*C*) *annealed, tungsten-carbide coated* 52100 *steel gauge block*



4 *Stabilities of:* (*A*) *commercial AA grade steel;* (*B*) *nitrided* 410 *stainless;* (*C*) *stabilized* 52100; (*D*) *annealed* 52100 *coated with tungsten carbide. Figures are averages of measurements on all blocks of each type*

positioned between the measuring styluses in comparing their lengths.

Before either of these precision techniques is applied, the gauge blocks are inspected for flatness of surface and parallelism of gauging faces. Only those that meet certain rigid specifications are acceptable for stability testing. Preliminary measurements of linear thermal expansion are also made. For the dynamic comparisons, test specimens can then be divided by thermal properties into groups so that identically handled blocks will have identical responses.

One block in each group is selected as a secondary master and, after being compared with the primary master interferometrically, is compared with blocks in its own group by the mechanical technique. To meet the requirements of like handling of all test specimens, the secondary master is treated as one of the test specimens. All possible comparisons, $n(n-1)$ comparisons on $n(n-1)/2$ pairs, where n is the number of blocks in a group—form one test. In the tests, groups containing 11 gauge blocks were compared, in other words 110 comparisons on 55 pairs.

The measurement data are then reduced by the method of least squares to provide a calculated value for each comparison. The difference between the calculated and observed values is used to determine the probable precision of results.

Application of results

These frequency distributions served as a powerful tool in developing a satisfactory measuring technique, precise to $0 \cdot 2 \times 10^{-6}$ in. They have been used to establish the relationship between calculated probable error and the precision actually realized; to demonstrate the successful elimination of bias from the comparison procedures; and to locate sources of systematic error.

For example, residual frequency distributions have been very effective in prescribing a handling procedure for a two-block test set. Obviously an operator can handle blocks manually with greater ease and assurance than with tongs or other tools which introduce the danger of dropping. Using insulating gloves, the operator would therefore pick up two blocks simultaneously by their non-gauging ends and position them in the comparator in what was considered symmetrical handling. However, it was soon revealed that the manner in which the blocks were held had a significant effect on the symmetry of the residual frequency distributions. It was concluded that handling was producing an unsymmetrical thermal effect—the blocks were held perpendicularly so that one was nearer the operator's palm than the other. After the procedure was changed so that blocks were picked up in tandem with their non-gauging ends facing the palm, the statistical distributions showed the expected symmetry.

Of the 16 materials under study at the Bureau, only blocks of two materials, 410 stainless steel and 52100 modified steel, have been observed for a year. The most stable blocks were made from the annealed 410 stainless steel, nitrided to a depth of 0·009 in., ground to within 0·003 in. of finished length, stress relieved for 3 h. at 520°C. in a cracked ammonia atmosphere, and then finished by lapping the gauging surfaces, leaving a case of about 0·005 in. The nitrided non-gauging surfaces when left intact have a frosty grey appearance. Similar stability was indicated by blocks whose frosty layer was removed by further grinding (fig. 3).

The best through-hardened 52100 steel gauge blocks were not quite as stable as the two nitrided

continued on page 418

BOOKS

Lead and lead alloys for cable sheathing

By S. A. Hiscock. Ernest Benn Ltd. Pp. 361, 161 illustrations, 55 tables. £3 10*s*. net.

A COMPLETE HISTORICAL survey of the development of extrusion machines and techniques is first made and a very interesting chapter this proves to be. The author has quite rightly given a full description of the various developments and this introduction includes naturally the process of continuous extrusion.

The author then goes on to deal with extrusion presses and machines in detail, including the Henley continuous-extrusion machine which is now no longer used. The importance of die block design is considered, as also is the effect of container and billet size—the selection of materials for tooling purposes is not considered.

A short but adequate chapter is devoted to ancillary equipment.

The requirements of lead cable sheaths and the effects of service conditions and other variables on their general behaviour is considered very fully. Fundamental metallurgical considerations of fatigue and creep are discussed and their relationship to grain size, temperature and other effects are brought out. The author has well illustrated the influence of actual service conditions to those metallurgical defects which are most likely to occur.

An interesting chapter is given on lead cable sheathing alloys with a fully documented table of currently used compositions. These metals are discussed and the influence of alloying elements on the general behaviour of each type is considered, particularly with respect to creep and fatigue and also the susceptibility to age hardening.

One feels after reading the section on aspects of flow of lead during extrusion whether the author could have made better use of the grid type of flow pattern to illustrate his discourse on the fundamental types of flow encountered in direct and indirect extrusion. However, an interesting explanation of the flow of lead in cable sheathing then follows and the complicating factors, *i.e.* division of lead and ' charge weld regions,' are shown to be important.

The author then goes on to consider the defects and features of the cable sheaths, outlining the factors influencing their formation and also the methods available for elimination or mitigation of them.

The effect of welding variables, deformation, pressure, temperature, oxide, etc., are dealt with. Factors influencing production and characteristics of stop marks, particularly the relationship of the latter to grain size and creep, make interesting reading and one could only wish for a few more photomicrographs to illustrate the individual cases referred to.

As a natural follow-up to the preceding chapters the effect of extrusion techniques on product quality are now dealt with—that is, the melting of the lead itself, with special reference to the influence of alloying additions on oxide formation, methods of casting and solidification and also the effect of straining with special regard to the production of zoned structures.

A chapter devoted to the interrelationship of extrusion variables and their effects principally on grain size and stability of the product proves most interesting.

Mr. Hiscock has presented here the work of many investigators and summarized it in such a manner that it has not become disjointed. The effects of temperature, pressure, composition, stability and grain size are all discussed.

Individual chapters in this book conclude with a general summary, a practice which many other authors would do well to adopt.

The book ends with a more detailed study of the practice of continuous extrusion and also comments on likely future developments.

Very little data has been published on the production and the properties of lead for cable sheaths and this fact has been somewhat surprising, particularly in view of the importance of the product.

As the author points out in his preface this is the first work devoted exclusively to the subject of lead cable sheathing and, whilst the book is aimed at technologists in the cable works, its contents will be of interest to all students of metallurgy and engineering.

The book is well produced and adequately illustrated with reproduced photographs, line drawings and photomicrographs, although the quality and quantity of the latter could possibly be improved.

In conclusion it can be said that the volume goes a long way towards fulfilling the long-felt need for information on this subject and on this account can be completely recommended.

H. J. SOUTHAN

Metalsmithing for the artist-craftsman

By Richard Thomas. Sir Isaac Pitman & Sons Ltd., London, 1961. Pp. 173. £2 5*s*.

THIS AMERICAN BOOK consists of descriptions, usually brief, of the fundamental processes involved in the manufacture of metal articles by hand (spinning and centrifugal casting are borderline industrial processes also described). It does not cover the allied fields of enamelling, embossing, engraving, chasing and so forth, although many of the photographs of fine examples are of material so treated.

The text at its best is forthright and practical, at its worst prolix. The many photographs are clear; the diagrams are the best feature of the book—large, bold, simple and self-explanatory as a good road-sign. It is unfortunately one of those books in which text and illustration are constantly getting out of phase with each other, and one finds all the fingers of one hand employed as book-markers.

In some respects the book is unbalanced. A flange, for instance, may be raised on the edge of a metal disc by hammering it when tilted against a stake. Mr. Thomas takes over 300 words to say this, along with four giant diagrams and a dissertation upon the principle of leverage. The final crucial process of planishing, on the other hand, is dismissed with 35 words and one photograph.

There is no glossary, which is surprising in a book dealing mainly with elementary workshop practice. Terms are sometimes explained, sometimes not. Perhaps the reader should already know, or be able to guess, what is meant by ' upsetting, ' ' sprue-hole ' or ' burn-out, ' but he is unlikely to need reminding that ' filing is the removal, smoothing or levelling of gross surface irregularities of the raised, cast or fabricated piece. '

It might be as well to point out to the gentle reader who may be inspired to try his hand at this ancient craft, that the pickling process is aimed at the artefact and not the operator. If he wishes to survive to complete his article he should not be deceived by one of the writer's fits of verbal economy in which he omits the vital word ' slowly ' from the recipe, nor by the admirably clear diagram of a basinful of acid being tipped into a basinful of water.

HAMILTON WOOD

Work study

Use of method study in the drop-forging industry

W. A. REYNOLDS

It is more and more becoming apparent that there are few industries which would not benefit from the important study of their production routines by the trained specialist in work study. As an example of the kind of improvements which can result, four case studies from the drop-forging industry are summarized in this article. The paper is based on the talk given by the author, of Birmingham Productivity Association Technical Advisory Service Ltd., to the National Association of Drop Forgers and Stampers at the 1961 *Annual Convention held at Eastbourne last June*

WORK STUDY is a common-sense practical tool of management with an application to most activities in a manufacturing enterprise.

It has been defined as follows:*

'*Work study* is a term used to embrace the techniques of method study and work measurement which are employed to ensure the best possible use of human and material resources in carrying out a specified activity.'

Method study and time measurement, in turn, are defined as follows:

'*Method study* is the systematic recording, analysis and critical examination of existing and proposed ways of doing work and the development of easier and more effective methods.'

'*Work measurement* is the application of techniques designed to establish the work content of a specified task by determining the time required for carrying it out at a defined standard of performance by a qualified worker.'

Problems that can be tackled

The conventional field of work study investigation is any operation, from typing a letter or entering an order to operating a hammer or press, which is repeated frequently. It need not be a production operation—many savings can be made in office work, where work study goes under the name of *organization and methods.*

Apart from the conventional applications, it has been shown that many maintenance or one-off jobs can be made quicker and easier by method study investigations. Overhaul times for capital plant, such as presses, oil refinery units, rolling mills, have been reduced very substantially in this way.

It is often found that great savings can be made in administrative work and these usually benefit production on the shop floor. Design and drawing offices, where work is not repetitive, are not usually a fruitful field, although an associated technique called *variety reduction* helps to keep people from designing unnecessary new components.

Having indicated the broad field of work study, this paper will now be confined to manufacturing production applications, with particular reference to the drop forging industry. Fig. 1 (which is not to scale) shows how the manufacturing time of an article is made up. Each of these sections of unnecessary time can be subdivided into many contributory causes. The curious thing is that most of these causes have their roots in management decisions—decisions we have given which, on the evidence available, were probably right, but unknown to us have wasted a great deal of time. The object of work study is to reduce this ineffective, wasted time.

It will usually be found that the operator, the man on the hammer, cannot expend much more physical effort—work study helps to find out how much of his effort is usefully employed in producing a saleable article. It will normally be found that the amount of ineffective or wasted time which is under the worker's control is much less than the amount under management control.

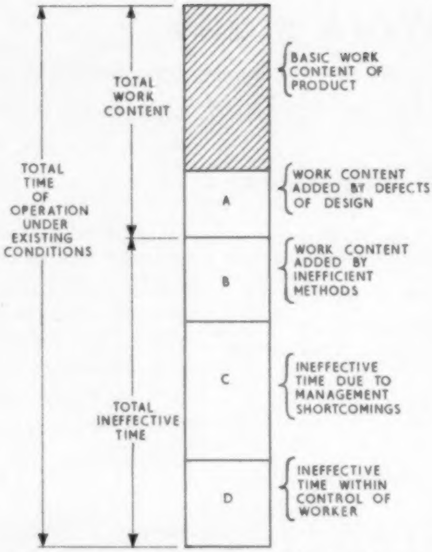
Basic procedure of work study

There are eight basic steps in performing a complete work study, three of which are common to the

* Most of the definitions in the text have been taken from 'Introduction to Work Study,' I.L.O.

procedures of both method study (M.S.) and work measurement (W.M.), three are method study steps and two are work measurement steps. They are:

1. *Select* the job or process to be studied (M.S. and W.M.).
2. *Record* from direct observation everything that happens, using the most suitable recording techniques available, so that the data will be in the most convenient form to be analysed (M.S. and W.M.).
3. *Examine* the recorded facts critically and challenge everything that is done, considering in turn: the purpose of the activity; the place where it is performed; the sequence in which it is done; the person who is doing it; the means by which it is done (M.S. and W.M.).
4. *Develop* the most economic method, taking into account all the circumstances (M.S.).
5. *Measure* the quantity of work involved in the method selected and calculate a standard time for its performance (W.M.).
6. *Define* the new method and the related time so that it can always be identified (W.M.).
7. *Install* the new method as agreed standard practice with the time allowed (M.S.).
8. *Maintain* the new standard by proper control procedure (M.S.).



1 *Diagram showing how manufacturing time is analysed*

Work study—who should do it

Work study succeeds because it is systematic both in investigation of the problem being considered and in the development of its solution. Systematic investigation takes time and it is necessary, therefore, in all but the smallest firms to separate the job of making work studies from the task of management. Only by continuous study at the workplace or in the area where the activity is taking place can the facts be obtained. This means that work study must always be the responsibility of someone who is able to undertake it full time, without direct management duties.

Method study in the drop forging industry

The following examples of the use of method study are taken from recent work done in the drop forging industry. The studies were done by the work study staff of the firms concerned and not by the B.P.A. T.A.S., who are greatly indebted for the help they have been given in this matter.

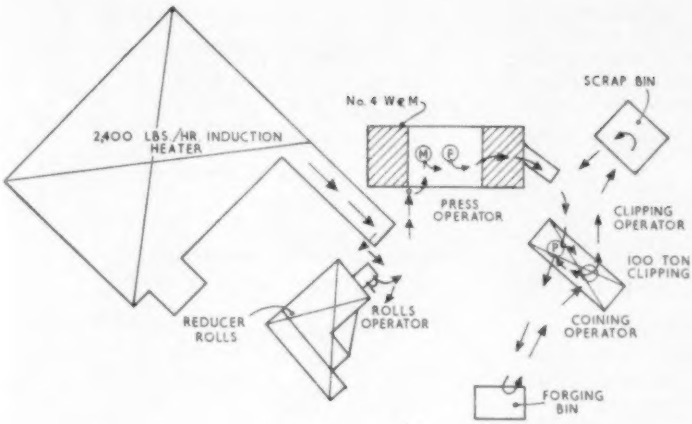
Case study 1—forging a connecting rod

This study is related in some detail to show the methods used. It was undertaken to improve the output from a No. 4 Wilkins & Mitchell press working in conjunction with a 100-ton Wilkins & Mitchell clipping press and a 2,400-lb./h. induction heater. The original layout of the plant is shown in fig. 2. The movements of the work piece and the operators were carefully recorded on special study sheets and then transferred to an analysis sheet. The total number of movements is shown in column 1 of table 1. No measurement of time was made with a watch and all the movements were recorded by observation and not with a cine-camera. It will be seen that in the original method the crew made 99 movements in each cycle and the work piece and its flash travelled 651 in.

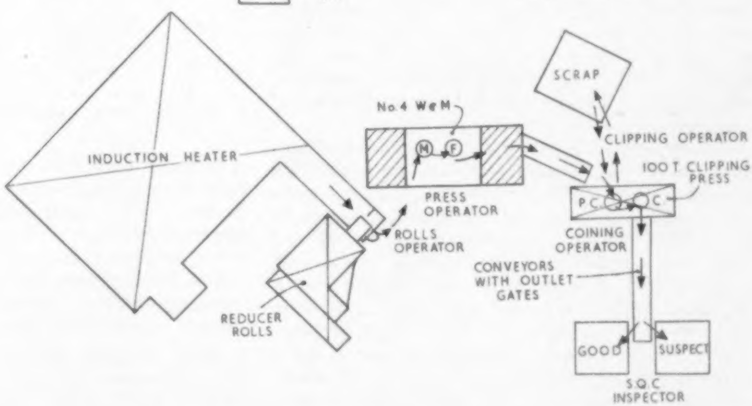
TABLE 1 *Forging connecting rod. Summary of crew movements*

	Existing method/layout movements	Proposed method/layout movements	Improvement savings
Left hands ..	29	22	7
Right hands ..	40	27	13
Left feet	16	—	16
Right feet ..	14	4	10
Totals per cycle ..	99	53	46
Distance per cycle	651 in.	288 in.	363 in.

In order to evolve a better layout the Work Study Department made mock-ups of the plant, using chairs, tables, desks and cardboard models of tools and dies, etc., in their own office. By going through the cycle and asking themselves why, what, where and how they evolved new positions for the plant and a new series of movements. The new movements and layout are shown in fig. 3 and a summary in column 2 of table 1. It will be seen that the total movements were reduced from 99 to 53 and the



2 *Forging a connecting rod —original layout*



3 *Forging a connecting rod —improved layout*

distance the work piece moved from 651 to 288 in. The co-operation of the Die and Tool Design Department was obtained and the procedure simplified by combining forging operations. It will be seen that the alterations are as follows:

1. The heater conveyor was modified so that the billet was presented to the operator ' end on ' underneath the bottom roller. The operator can then easily grip it with his tongs.

2. The reducer rolls have been re-positioned so that the operator can move the rolled billet from the machine direct on to the mould die without moving his feet.

3. A solenoid time-relay switch was built into the back stops of each rolling station so that the insertion of the billet to the correct position starts the rolls. This eliminates the foot-operated switch.

4. The job of placing the billet in the moulding die was transferred from the press operator to the roller.

5. The clipping press has been moved to give a shorter travel and more space.

6. Combination tools have been introduced for the piercing and clipping operation. This was done so that the piercing and clipping is in phase with the coining operation.

7. Installation of a vibro conveyor for the purpose of:

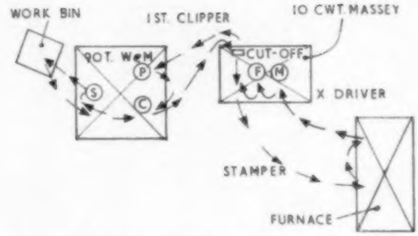
(*a*) Moving forgings from the clipping press to the finished work bin without damage. The proportion of work requiring straightening was very much reduced by this.

(*b*) Facilitating inspection. The conveyor holds 20 forgings and the patrol inspection comes round sufficiently often so that it is never full. When the patrol inspector has looked at the forgings, he separates them into good and suspect. The effect of this is that a maximum of 20 pieces are forged before inspection instead of 500 previously.

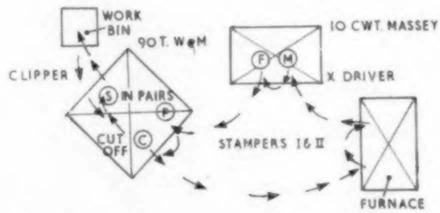
Expressing these figures in another way, the movements per 400 pieces were as in table 2. Although the alterations have only just been completed, the output per hour has increased in proportion with the savings per hour of 55% indicated.

TABLE 2 *Forging connecting rod. Movements per 400 pieces*

	Existing method	Proposed method	Savings/hour
Crew movements	39,600	21,200	18,400
Distance	21,700 ft.	9,600 ft.	12,100 ft.
Percentage ..	100%	44·2%	55·8%



4 *Forging a rocker arm—original layout*



5 *Forging a rocker arm—improved layout*

Case study 2—forging a rocker arm

The existing plant consisted of a 10-cwt. Massey hammer with a 90-ton Wilkins & Mitchell clipping press and an oil-fired furnace. The existing arrangement of the plant is shown in fig. 4. The investigation was undertaken to see what improvements could be made by using two stampers instead of one. The crew consisted of one stamper, one driver, one front clipping press operator and one rear clipping press operator.

All the movements which each member of the crew made were studied and investigated. No camera or stop watch was used for this; the work study engineer merely standing by and noting each movement. Their total movements are shown in the first column of table 3. The movement ' walk ' was excluded from the total, since each operator used a different length of step. When the existing practice had been fully recorded, the Work Study Department, with the co-operation of the crew, tried out a new arrangement using two stampers, one driver and one rear press operator. The plant and tools were unchanged. This rearrangement was unsatisfactory: extra movements were being made and the men were hesitating because they were in danger of running into each other.

The Work Study Department, therefore, decided to see what could be done by rearranging the plant and improving the tooling.

Different arrangements were tried out in the Work Study Office, using suitably-sized tables, etc., to represent the hammer, the press and the furnace, and the work study engineers finally evolved a satisfactory arrangement. The tooling engineers co-operated by designing:

(1) A combined cutting-off and clipping tool and
(2) A small tray which fitted under the clipping tool. The forgings fell into this and the rear press operator was able to reach over and slide the forgings from the tray into the setting die.

The new layout is shown in fig. 5 and the movements were analysed, with the results shown in column 2 of table 3. This new layout of plant, operational procedure and movement pattern was then demonstrated in the Work Study Office to members of the management and work supervision. Approval was given for it to be put into practice and the actual plant was moved.

The whole of this study, the observation and the recording and working out of new method, up to the stage of try-out in the shop, took 36–40 man hours of the Work Study Department's time. The original average production per hour (working on incentives) was 260 pairs. On the test run, with the men working on time rates, 520 pairs per hour was achieved and it is expected that the ultimate rates per hour, with the men on piecework, will be considerably higher.

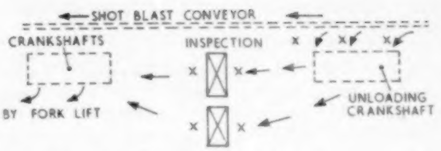
TABLE 3 *Massey 10-cwt. hammer. Forging rocker arms in pairs. Summary of crew movements (walking excluded)*

	Existing method Col. 1	Proposed method Col. 2	Savings Col. 3
Left hands	49	48	1
Right hands	59	35	24
Left feet	7	2	5
Right feet	8	8	—
Totals per cycle ..	123	93	30

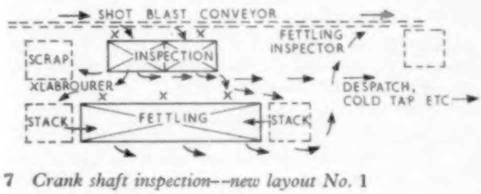
Previous average per hour	260 pairs
Test run rate per hour	520 ,,

Case study 3—crank shaft inspection

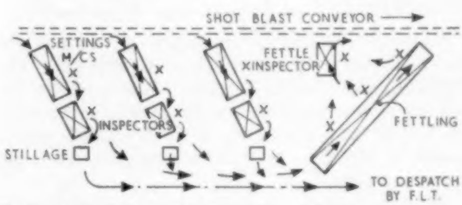
The problem in this case was increasing the output in the Inspection Section, which was causing a serious hold up. Requirements were 1,000+ a day and the average output achieved was about 680.



6 *Crank shaft inspection—original layout*



7 *Crank shaft inspection—new layout No. 1*



8 *Crank shaft inspection—new layout No. 2*

The original layout is shown in fig. 6. It will be seen that three men unloaded the crank shafts from the shot-blast track and stacked them. The first pair of inspectors lifted shafts from the stack and put them on the inspection table, where they were viewed between the two inspectors for surface flaws and general straightness. (It was noted that frequently some parts were looked at twice and others not at all.) The other inspectors then removed the shaft and placed it on another stack, from where it was moved by a fork-lift truck.

The investigation showed that:

(*a*) Approximately 30% of available inspectors were engaged on manual transport and stacking of forgings over a considerable area.

(*b*) Working speed varied according to the urgency of the forgings with which they were dealing.

(*c*) Transport facilities were inadequate.

(*d*) Inspection was only one of a series of operation and movement sequences requiring investigation if productivity was to be increased.

The Work Study Department first proposed that the inspection and the fettling should be brought to the same area so as to reduce both mechanical and manual handling. The arrangement is shown in fig. 7.

Two inspectors remove the crank shafts from the track, inspect and mark up. The labourer collects the inspected crank shaft and places it as instructed: good work for despatch; cold tapping; fettling; scrap. He also loads fettled crank shafts on to the track for re-shot blasting. The fettlers were now brought alongside the inspectors, had their work inspected immediately and returned to them, if necessary. This set-up enabled the section to increase their output to over 1,000 per day. It was still necessary, however, for the crank shafts to be moved from the Inspection and Fettling Section for straightening and brought back again for re-inspection. It was therefore decided to combine straightening, fettling and inspection on one site, and this was done. The final arrangement is shown in fig. 8. The main points of this are:

(1) Setting was carried out prior to inspection and the inspector checked the straightness in the setting machine prior to its removal and inspection for surface flaws.

(2) Work requiring fettling was done immediately and inspected prior to re-shot blasting. (The second shot blasting is carried out so that a uniform appearance is given and liability to rusting on the fettled edges reduced.)

(3) The arrangement ensured that all work was inspected before going to despatch.

(4) The arrangement enabled an incentive bonus to be applied to each of the separate groups: setters; inspectors; fettlers.

The result was that the section is able to deal with all present work easily and any expected increase (table 4).

TABLE 4 *Crank shaft inspection. Summarizing the improvements*

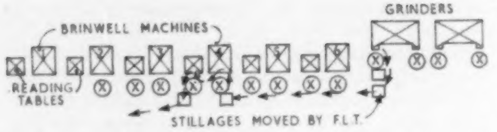
	Original	Layout No. 1	Layout No. 2
Inspectors	4	3	4
Labourers	3	1	–
Output . .	680/8½ h.	1,000+/8½ h.	2,300/8½ h.

Case study 4—Brinell testing machines

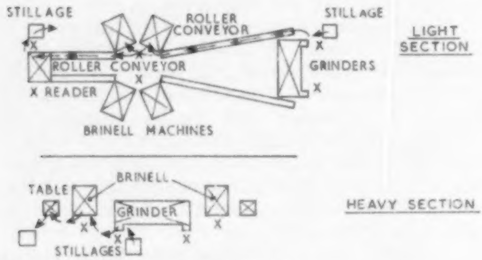
This investigation illustrates the reductions in cost and manual labour that can often be achieved by a study of non-production operations. In this case the Brinell Hardness Testing Section was overloaded and, naturally, there was a request for something to be done—either more machines or more overtime, or both. An investigation was undertaken and, following the rules, the facts about the section were first obtained:

(*a*) The plan and area.

(*b*) The number and type of machines and equipment.



9 *Brinell testing—original layout*



10 *Brinell testing—new layout No. 1*

(*c*) The number of people employed, the hours they worked and the range of components tested.

The original arrangement is shown in fig. 9. It will be seen that this is a conventional layout with two twin-wheel grinding machines and six Brinell testers. All the components to be tested were brought to the grinding machines in stillages by fork-lift trucks. After grinding the test surface the stillages were moved down to whichever machine had the least amount of work. Components were taken from the machine by the operator, the load applied and then passed to the table alongside, where the reader measured the impression. The operators and readers changed places every hour to relieve eyestrain. Difficulties experienced were:

(*a*) Ensuring that the Brinell machine operators applied the load for at least the minimum prescribed period.

(*b*) Moving material: the fork-lift truck never seemed to be available when required.

The section output was 5,000 components per 8½-h. day and a summary is shown in column 1 of table 5.

The investigation made use of the production sheets kept by the operators to find:

(*a*) Monthly and weekly output figures.

(*b*) Difference between actual and required total output (by comparison).

(*c*) Variation in output rates per hour according to weight and size.

(*d*) Variation in operator productivity.

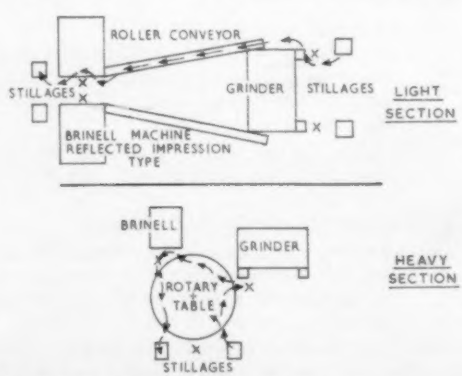
Acting on these facts and figures, it was decided to divide the components into two categories: those over 10 lb. weight and those under 10 lb. weight.

TABLE 5 *Brinell testing. Output, equipment and staffing comparisons*

	Original layout	New layout No. 1	New layout No. 2
Average total output per 8½ h.	5,000	9,340	10,490
No. of grinding machines	2	2	2
No. of Brinell machines	6	6	3
No. of readers' tables ..	6	3	—
Total of pieces of plant..	14	11	5
No. of operators/readers	12	10	7
No. of grinders	4		
Total men	16	10	7
Output per man hour ..	36·7	110	176
Percentage increase ..		170%	60%

Analysis of the actual operations carried out and the time spent in doing them showed that there was a great deal of manual handling of components and waiting for the previous operation to be completed. An entirely new layout was then developed: this is shown in fig. 10. It will be seen that the main points are these:

The heavy work has been allotted its own grinder and Brinell testing machine. The light work section has been laid out with roller conveyors to take the work from the grinders to the Brinell machines, and one operator looks after two machines; setting up or removing work from one while the load is applied on the other. This helps to ensure the minimum required dwell and relieved supervision. The trays of work then travel on a roller conveyor to the readers at their table. Operators, grinders and readers all change round at hourly intervals. A summary of the machines and men required and the output achieved is shown in column 2 of table 5.



11 *Brinell testing—new layout No. 2*

The Brinell machines used in the original and the new layout were standard orthodox pattern. It was, however, decided to purchase two new Brinell machines where a reflected image of the impression is read directly by the machine operator. This removes the necessity for a separate reader. At the same time it was decided to improve the work handling for the heavy section, which, it will have been noted, was virtually unchanged in principle from the original layout. A variable-speed rotating table was employed to carry work to the grinder and thence to the Brinell machine, which was also of the new type. A labourer loads and unloads the table which brings the components alongside the operators, relieving the need for bending and lifting. The final results are shown in column 3 of table 5 and the No. 2 layout in fig. 11.

It will be noted that the original increase of 170% per man hour was obtained by rearrangement of existing plant and the use of roller conveyors. Some of the subsequent increase of 60% was due, of course, to the use of the new type of testing machine, which has a set $3\frac{1}{2}$ sec. dwell.

Work measurement

It has been seen in the case studies described how unnecessary movement can be eliminated. This is very important, but it is also important to measure what has been achieved in terms of time. If the time of a new method is measured, it sets a standard by which future performance can be judged. These time standards will continue to apply as long as the work to which they refer continues to be done and will show up any ineffective time or addition to the work content which may occur once they have been established.

In the process of setting standards it may be necessary to use work measurement:

(*a*) To compare the efficiency of alternative methods. Other conditions being equal, the method which takes the least time will be the best method.

(*b*) To balance the work of members of teams, in association with multiple-activity charts, so that each member has a task taking an equal time to perform.

(*c*) To determine association with man-machine charts the numbers of machines an operator can run.

Ways of measuring time

It may be objected that the only way to measure time is with a watch. There are, however, several derived methods which are in common use as well as orthodox stop-watch study of times taken on the job. These are:

Ratio-delay A sampling technique which gives information on the percentage of time a number of people are spending on different sections of their jobs.

Synthetics This method uses times previously obtained by observation of different parts of many jobs. These times will normally be common to that part of the job wherever it occurs. An experienced engineer can, therefore, build up a synthetic time standard from existing data.

Motion time measurement This is a very refined form of synthetics and it depends on analysing the movements required to do a job—grasp, lift, carry, etc.—and assigning times to them in accordance with standards. Using M.T.M. methods, times of manufacturing processes can be estimated with some accuracy from drawings. This can, however, only be done by experienced engineers with special training.

Analytical estimating This is a compromise between rate fixing and time study, useful in one-off jobs. It can be done by skilled craftsmen trained in work study, who analyse the processes involved in carrying out the work and assign times to each operation.

When the time taken has been measured it must be related to what is usually called a standard performance. This is the equivalent speed of motion of a man's limbs when walking on level ground at 3 m.p.h. What is known as 'rating' is the estimation of the actual performance to the standard. Many books have been written on the subject and arguments caused. It is the most difficult operation in work study engineering and calls for much experience.

Time measurement and production planning and costing

The time standards, once set, may be used:

(1) To provide information on which the planning and scheduling of production can be based, including the plant and labour requirements for carrying out the programme of work and the utilization of available capacity.

(2) To provide information on which estimates for tenders, selling prices and delivery promises can be based.

(3) To set standards of machine utilization and labour performance which can be used for any of the above purposes and as a basis for incentive schemes.

(4) To provide information for labour-cost control and to enable standard costs to be fixed and maintained.

In other words, work measurement provides the basic information necessary for all the activities of organizing and controlling the work of the factory in which the time element plays a part.

The great advantage of using time measurement

is that if the method is unchanged, so is the time—it will be the same in five months or five years—the same cannot be said for the value of money. Therefore, there is much advantage in keeping cost records in terms of time and converting only the totals into terms of money.

Close control can be kept over the performance of different departments by the use of time records, which are quickly and easily maintained once the basic time measurement standard has been established.

Work study and people

Because a well-conducted work study analysis is impartially systematic, the places where effort and time are being wasted are laid bare one by one: in order to eliminate this waste the causes of it must be looked for. These are usually found to be bad planning, bad organization, insufficient control or lack of proper training of workers. Since members of the management and supervisory staffs are employed to see to these things, it will look as if they have failed in their duties. Not only this, but the increases in productivity which the proper use of work study usually brings about further emphasize this failure. Applying work study in one shop can start a chain reaction of investigation and improvement which may spread throughout the organization. The skilled worker may be made to feel a novice when he finds that his methods, long practised, are wasteful of time and effort and that new workers trained in the new methods soon surpass him in output and quality. Any technique which has such far-reaching effects must obviously be handled with great care and tact.

If the application of work study in an enterprise is to succeed, it must have the understanding and the backing of the management at all levels, starting at the top. If top management does not understand what the work study man is trying to do and is not giving him his full support, then it cannot be expected that managers lower down will accept and support him.

One of the most important people in any works is the foreman, and, whatever his background, the foreman may well resent the introduction of a work study man into his department unless he has had some training to prepare him for it. Since the foremen are nearer to the practical side of the job than the management, and so intimately connected with work study, they should be given a work study appreciation course. They should know enough to be able to help in the selection of jobs to be studied and to understand the factors involved should disputes arise over performance standards. This means that they should be acquainted with the principal techniques of method study and work measurement and the particular problems and situations in which they should be applied.

Generally speaking, courses should be full-time and of not less than one week's duration. Students should be given opportunities of making one or two simple method studies and of using stop watches. The value to the work study man of a foreman who understands and is enthusiastic about what he is trying to do cannot be over-emphasized.

Work study imposed on an unwilling body of staff by a dominating management is very unlikely to produce results, but with staff co-operation it is usually successful.

Gauge blocks

concluded from page 409

410 stainless types, but most of the instability occurred during the first six months of observation. The 52100 steel blocks were heat treated by austenitizing at 840°C. for 30 min. and quenching in an accelerated quenching oil; and stabilized by refrigerating at –96°C. for 18–24 h., tempering at 120°C. for 1 h., refrigerating a second time at –96°C. for 18–24 h., and tempering at 120°C. for 9 h. The blocks were ground and then stress relieved at 115°C. for 3 h. before a final lapping. This treatment reduces the unstable austenite to less than 2% and produces a block of satisfactory hardness.

A fourth block which shows promise, but which has been under study for less than a year, is of 52100 annealed steel coated on the gauging surfaces to a depth of 0·004 in. with tungsten carbide. After surface grinding and lapping, a coating of about 0·0025 in. remained, providing a hard facing. A 3-h. stress-relieving treatment of cracked ammonia at 975°F. was applied before lapping. An extrapolation of available data indicates that the overall growth of such a block is $0{\cdot}7 \times 10^{-6}$ in./yr., but a substantial improvement in stability during recent months suggests that a much higher stability may be achieved.

Several commercial hardened steel gauge blocks of the highest quality (AA grade) were purchased from different manufacturers and observed for stability in the same manner as the Bureau-developed blocks. All of these blocks become shorter, shrinking by an amount ranging from $0{\cdot}7 \times 10^{-6}$ in./in./yr. to $1{\cdot}9 \times 10^{-6}$ in./in./yr.—an average shrinkage of $1{\cdot}1 \times 10^{-6}$ (fig. 4).

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Research for the spring industry

Some aspects of the work of the Coil Spring Federation Research Organization

H. A. SNOW, A.I.M.*

THE COIL SPRING FEDERATION RESEARCH ORGANIZATION came into being in 1945, the governing body being the Coil Spring Federation, which was established some three years earlier as a war-time measure to overcome problems related to springs for weapons and fighting vehicles. Spring manufacture in the United Kingdom constitutes one of the smaller specialist industries serving a very wide range of other industries and the CSFRO is likewise one of the smaller centres for collective research.

For the first 12 years the research activities were confined to the universities, although it was realized from a long-term point of view that the industry should own and operate its own laboratories, thereby forming a centre of specialized knowledge and information on springs and spring materials. It was also considered to be in the national interest to work in close collaboration with the British Iron and Steel Research Association and this has now been brought about by the establishment of independent laboratories adjacent to BISRA in Sheffield. These laboratories were officially opened on March 24, 1960, by Sir Harry Melville, K.C.B., F.R.S., secretary of the Department of Scientific and Industrial Research.

In common with many other research organizations serving particular industries, the affairs are managed by a council elected by members and composed mainly of the leaders of the industry. Members provide the main part of the income and this is augmented by grants made available by the Government through DSIR to encourage development and growth, the grants being related to the amount of money put up by industry.

Membership

At the present time the CSFRO has a total membership of approximately 120 firms and, whilst numerically only about half of these are spring makers, they provide the majority of the financial support. Companies engaged either wholly or partly in the production of springs or spring press-work for the trade are eligible for ordinary membership, whilst manufacturers of spring quality wire and strip, spring users, and indeed any company or organization having an interest in the work of the Research Organization, may become an associate member.

Of special interest, it is felt, is the fact that since the CSFRO serves the needs of an industry producing

1 *Spring wire testing on a Haigh-Robertson rotating-bending fatigue machine*

*Industrial liaison officer of the CSFRO, which will in future be known as the Spring Manufacturers' Research Association, having now been admitted to full membership of the government's industrial research association scheme.

an end-product and the terms of associate membership permit a wide range of industries to be represented, close collaboration is possible between spring manufacturers, their suppliers of spring quality materials and their customers, the spring users. This collaboration between all the parties concerned is, in fact, a very real thing and reference to the list of members will indicate the names of many well-known companies in these three groups who are working together on problems of mutual interest.

Research facilities

The successful design, manufacture and performance of springs, whether produced from bar, rod, wire or flat strip, requires in the first instance a full knowledge and understanding of the spring material, its properties and the manner in which these can be improved by special treatments, etc. Hence the emphasis of the early research work and much of the present programme has been on spring materials.

In this field metallurgical examination, hardness and tensile testing are established as routine procedures, whilst special equipment has been installed for the fatigue testing of heavy and light springs, for static torsion tests and rotating-bending fatigue tests on spring wires (fig. 1).

Of equal importance to the properties and performance of springs is the type of surface treatment or finish and the facilities include an electroplating laboratory, shot-peening plant and fatigue testing in a corrosive environment. Special non-metallic protective coatings are also investigated.

Many spring materials require special heat treatments during manufacture and also as a final process applied to the manufactured spring. To enable a close study of these factors to be made a fully equipped heat-treatment laboratory has been established. The behaviour of springs operating at elevated temperatures is also studied here.

Research programme

The early research work carried out at a number of universities and the more recent work at the laboratories in Sheffield has already been of considerable advantage to members. Spring manufacturers can now apply closer technical control, backed by facts and figures to such processes as electroplating, shot-peening, pre-stressing and heat treatment, whilst both makers and users are able to design for greater efficiency, longer life and heavier duty from available materials.

Much of the research work is of necessity a long-term programme and as information becomes available the results are put into practice. Among projects which are in hand at the present time may be mentioned the fatigue properties of a wide range of spring materials, both ferrous and non-ferrous, the assessment of high-temperature alloys for springs, the control of hydrogen embrittlement during plating, factors affecting the life of heavy vehicle springs, copper-beryllium alloys, the investigation of new spring materials and the development of improved automatic coiling machines.

Industrial liaison

The most recent addition to the activities of the CSFRO has been the introduction of the Industrial Liaison Scheme. This is designed to provide a service to members anxious to discuss and put into practice developments arising from the research work carried out at the laboratories in Sheffield and projects carried out with the collaboration of the universities. It also provides a means of maintaining close contact with industry on subjects which might provide a basis for future researches.

One of the great problems facing all our engineering industries today is that of communication and the interpretation of technical developments from research level to the shop floor. With this object in view, one or more liaison officers active in the industries served by the Research Organization are necessary and the approach to the subject should be essentially that of practical technology as distinct from the research aspect.

The Liaison Scheme of the CSFRO, which is still in the process of development, has three primary objectives: (1) Personal visits to members to discuss the work of the laboratories and its application; (2) on-the-spot investigations arising from problems reported to the organization and the provision of a technical information service; and (3) visits to potential members with a view to enlisting their support for the work of the Research Organization.

Conclusion

It is perhaps appropriate to conclude on the subject of membership recruitment, as more than one industry has been the subject of criticism recently on the grounds of lack of technical progress and investment in research. Some 10 months of industrial liaison in the spring industry and associated industries has shown a lively interest to exist and, furthermore, a readiness to support the work, which is most encouraging. The membership and industrial income curves are climbing steadily and this can only result in an increasing rate of technical progress to the advantage of all concerned. Due acknowledgment is made to the Council, the Director of Research and members for their support and guidance in this work.

Marworking high-speed steel

RICHARD F. HARVEY

THE METHOD of mechanically working steels in the metastable austenitic condition for improved physical properties was developed by the writer and results were first published during 1951.[1]

Basically the method involves working the steel in the metastable austenitic condition above the temperature of martensite formation and below the nose of the transformation curve where pearlite forms readily. A diagram representing the process of 'interrupted quenching—hot working' or 'marworking' is given in fig. 1. The method has been patented.[2]

The present article relates to the use of this treatment on high-speed steels. In this investigation ground pieces 1·025 in. square, 6 in. long, of M-2 high-speed steel were used. One set of specimens were austenitized at 2,225°F. (1,220°C.) in an atmosphere furnace for 5 min. at temperature. The intercept grain size developed was 11½, as illustrated in fig. 2. The hardness on air cooling to room temperature was 64 Rockwell C.

A duplicate set of specimens were deformed on cooling from the same austenitizing temperature. On cooling to 1,000–900°F. (540–480°C.), a pressure of 1,500 tons was applied in one direction on an Erie press. The thickness was reduced to 0·612 in., which is a deformation of about 40·2%. The hardness was Rockwell C 66½ and the microstructure at ×1,000 in the untempered condition is as illustrated in fig. 3. Severe deformation and flattening of the austenitic grain structure will be observed.

A duplicate set of specimens was deformed in two directions 90° apart using a pressure of about 400 tons. The structure in the as-hardened condition is illustrated in fig. 4 at ×1,000. Severe deformation and transformation along the slip lines will be observed.

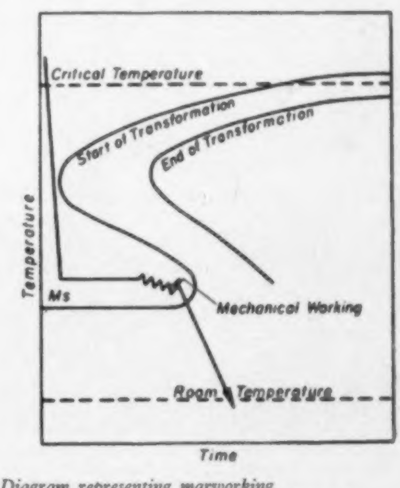
Deformation of high-speed steels in the metastable austenitic condition results in work hardening and transformation of a part of the austenite to martensite. In addition the normal austenite to martensite conversion occurs on cooling below the M_s temperature to room temperature resulting in a greater overall transformation to martensite and higher hardness than would occur without the mechanical working. Elimination of substantially all of the retained austenite is believed to account in part for the improved hardness and mechanical properties which may be expected on high-speed steels as a result of this treatment.

For reference the hardness obtained on tempering conventionally hardened and marworked high-speed steel is as follows:

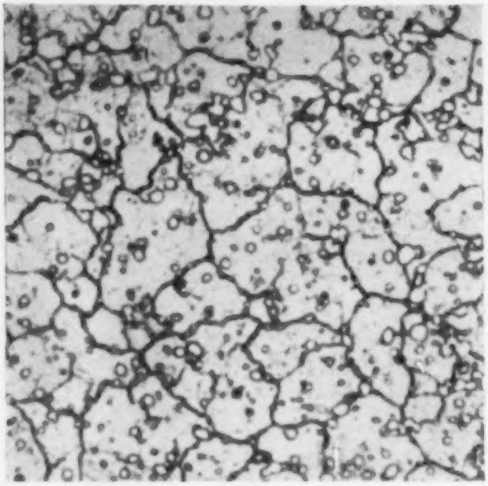
TABLE 1 *Hardness of M-2 high-speed steel compared for conventional hardening and marworking*

Treatment	Hardened 2,225°F. (1,220°C.) air-cooled (Rockwell C)	Hardened 2,225°F. (1,220°C.), pressed at 1,000–900°F. (540–480°C.) (Rockwell C)
As hardened	64	66½
Tempered:		
900°F. (480°C.)	63½	66
1,000°F. (540°C.)	65	66
1,025°F. (550°C.)	65	66
1,075°F. (580°C.)	63½	66
1,125°F. (605°C.)	60½	63½

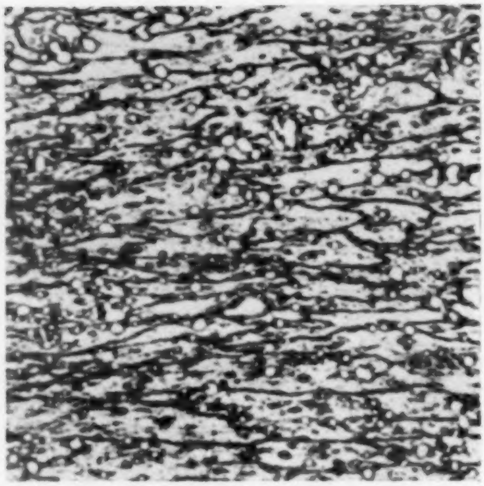
An increase in hardness of several points Rockwell C may be obtained on high-speed steels by hot-cold working. Also rather pronounced structural changes result. In view of these observations and in consideration of the highly beneficial results of this treatment on alloy steels, it is very likely that the treatment may also be of value on high-speed steels for cutting applications. It is also believed to be feasible to form, or to partly form, some types of cutting tools to shape in the meta-



1 *Diagram representing marworking (Copyright 1952, U.S.A., Richard F. Harvey)*



2 *Conventional hardening. Grain size* $11\frac{1}{2}$



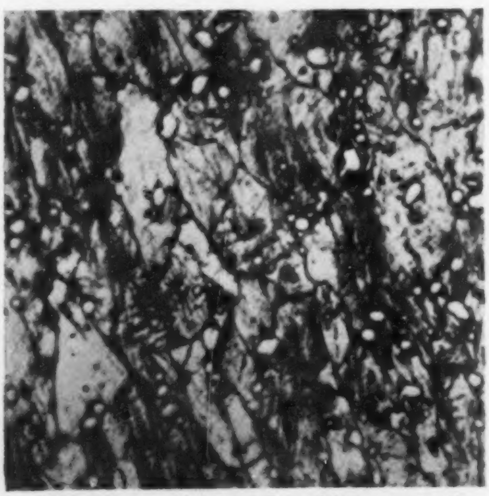
3 *Marworked one direction. Pressed* 1,500-*tons*, 540–480°*C.*

stable austenitic condition to effect savings in manufacturing costs.

As far as it is known, extensive cutting tests have not yet been conducted on high-speed tools treated by marworking. The metallographic and hardness data presented are of a preliminary nature to be supplemented by a more complete report when additional information is available. Cutting tests are in progress but the author is not yet able to report results.

It is significant also to note that marworking of other tool steels has been used with successful results. Since the early fifties, hubbing of die cavities has been done in the metastable austenitic condition on shock-resisting tool steels. This procedure results in a marked increase in die life.

With keen competition from cemented carbides and ceramics, many developments have been made throughout the years to modify and improve high-speed steel compositions and heat treatments. These comments on the marworking of high-speed steels are submitted with the belief that this technique will play a part in the advancement of high-speed steel technology as it has on other steels.



4 *Marworked two directions. Pressed* 400-*tons, two directions,* 90° *apart,* 540–480°*C.*
Microstructures M-2 high-speed steel. Austenitized 5 *min. at* 1,220°*C. Air-cooled. Nital etched* × 1,000

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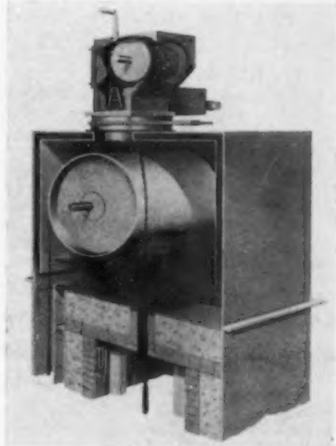
High-production electric furnace for continuous bright annealing



Cut-away diagram of top portion of the General Electric (U.S.A.) high-production furnace

THE INDUSTRIAL HEATING DEPARTMENT of the General Electric Co. in the United States has recently developed a new type, high-production furnace for continuous bright annealing of stainless-steel strip.

The furnace allows bright annealing at production rates as high or higher than existing anneal and pickle lines at approx. 50% lower cost per ton. Extensive tests on various types of stainless strip processed in the department's laboratory prototype furnace have shown improved corrosion resistance, appearance and physical properties over strip annealed by conventional methods, preventing the formation of scale on the strip through the utilization of very pure and dry (–60°F. dewpoint) hydrogen or dissociated ammonia atmosphere. At this dewpoint, the atmosphere is 99·995% dry. Thus the strip does not require passes through pickle baths to remove scale.

Vertical construction of the furnace makes possible a reduction in the amount of floor space necessary and assures that minimum tension is placed on the strip during annealing. The strip is heated and cooled during the single downward pass through the surface, where it touches nothing but pure, dry atmosphere while still at elevated temperatures. High tensions associated with horizontal catenary furnaces, which can reduce gauge and width and distort the strip, are not required.

Operating method

Stainless-steel strip is fed into the furnace in an inverted ' U ' pattern after it has been cold rolled. The strip moves up the back side of the furnace until turning over the top roll and then downward for the heating and cooling pass.

On the downward pass, the strip first enters the heating chamber where it is reapidly heated to annealing temperature by direct radiation from molybdenum heating units. The insulation system permits operation of the furnace at high temperature with high - purity atmosphere without muffle construction.

After reaching annealing temperature, the strip moves down into the adjacent cooling chamber where it is rapidly cooled by high-velocity hydrogen or dissociated ammonia. This specialized, high-velocity, jet-cooled system forces the atmosphere against the stainless strip at a right angle. As the atmosphere strikes the strip, a ' scrubbing ' action is produced which speeds cooling. The atmosphere is cooled by recirculation through water-to-gas heat exchangers.

The jet-cooling principle employs a number of self-contained, independent units with individual motors and heat exchangers which force the atmosphere against the strip. Each of these units is easily accessible for maintenance and inspection during operation.

When the stainless-steel strip reaches the delivery end of the furnace, it has been cooled to a temperature of approx. 90°C. and is ready for coiling. The exit seals are the first surface the strip touches after leaving the top roll on the downward pass.

The furnace is manufactured in two heights, approximately 54 and 75 ft. In a typical application —annealing type 430 stainless strip, 0·020-in. thick, at 1,100°C.—the furnace can handle 60 ft./min. of material. For strip 24 in. wide, the furnace would have a capacity of 6,000 lb./h. Furnaces are also produced to process strip widths of 12, 36 and 48 in.

Award for ' Noral News '

Noral News, the quarterly magazine of Alcan Industries Ltd., has been awarded a Certificate of Merit ' for high quality of content and presentation ' in the 1961 National House Journal Competition sponsored by the British Association of Industrial Editors. *Noral News* has received six awards altogether in the past few years, four of them in this annual British competition and two in the contest organized in the U.S.A. by the International Council of Industrial Editors.

NEWS

Henry Wiggin's new plant at Hereford

AN IMPORTANT industrial development in the metallurgical field in recent years is the new works of Henry Wiggin & Co. Ltd. at Holmer Road, Hereford. This plant represents the culmination of the company's modernization and concentration plan which is scheduled for completion in 1965.

Last month the company brought 20 of their overseas agents to Britain representing 13 different countries, as widely dispersed as Norway and Finland in the north, Greece in the south and Spain and Portugal in the west, to view for the first time the plant which, on completion, will be the largest and most modern of its kind in the world, comprising 25 acres of buildings on a total site area of 52 acres.

The visitors made a complete tour of the plant and laboratories and, in addition to talks by the chairman, Mr. I. A. Bailey, the managing director, Mr. H. W. G. Hignett, the sales director, Mr. R. E. Ansell, and other sales executives, saw an exhibition featuring applications of corrosion-resistant materials which had been specially staged for their visit.

Export training for management

An Export Training Centre for top management, the first of its kind in Britain, was opened recently at Sundridge Park, Kent. It has been set up by the existing Management Centre at Sundridge Park to help the country's export drive by providing comprehensive training facilities on a residential basis.

Three-week courses are being held at the Centre at regular intervals. They have been planned in consultation with a special advisory panel set up for the purpose by the Federation of British Industries, and are intended for managing directors, export directors and all senior sales executives concerned with the promotion of export business.

Subjects covered will include the selection of markets, the conducting of market surveys, appointment of selling agents, methods of determining prices, control of overseas sales forces and the most appropriate kind of advertising. Special attention will be paid to Common Market trading and selling to Communist countries.

Sundridge Park Management Centre was set up in 1955 as a non-profit-making educational trust by Personnel Administration Ltd., the management consultancy firm.

Firms requiring details about the new training facilities should apply to the Director, Sundridge Park Management Centre, Bromley, Kent.

Accident prevention for foremen

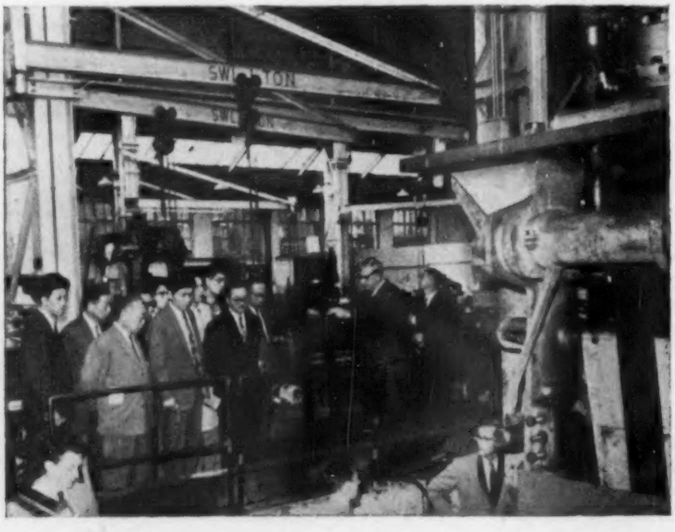
A new approach to accident prevention in industry by training foremen in safety measures, is being launched by the British Safety Council.

The Council is planning a nation-wide series of training courses directed at foremen. The courses, the first of which will be held in London in October, are being organized by Mr. Arthur Greenslade, who has joined the Council as head of the Training Division.

'The 25% increase in accidents to young workers over the past two years would suggest that present methods of accident prevention in factories are ineffective,' said Mr. Leonard Hodge, the Council's national director. 'We believe the foreman is the key figure in accident prevention. Unlike the safety officer, he is on the shop floor all day long, he can see where the faults lie and can talk more easily to the young workers,' he said.

In factories in other countries where foremen have been specially trained in safety, a significant reduction in accidents has generally followed.

The courses will last for four half-days, each followed by an examination. 'They will be held in most of the major cities, but we are prepared to hold them anywhere in the country where we can get 30 foremen together,' said Mr. Hodge.



Japanese trade delegation at B. & S. Massey Ltd.

The Openshaw works of B. & S. Massey Ltd., makers of forging and drop forging plant, was visited last month by a delegation from the Japanese drop forging industry. The 18-man party, led by Mr. Minekichi Kato, were on a two-day visit to this country to study at first hand equipment available to the drop forging industry. Welcoming the visitors, Mr. K. F. Massey, chairman and managing director, described recent developments in the design of the company's products. He explained that the present high proportion of export work was indicative of the company's capacity to compete with overseas manufacturers, and the exceptional range of forging plant available, together with the practical experience gained in the company's own forge, had led to its acting in a consultant capacity to a number of new forging plants under construction abroad.

So far, safety training has been in the form of written instruction, and as the figures illustrate—26,000 young workers injured in the last two years—this had insufficient effect. The Council are confident that, by training the foremen to a high standard of safety consciousness, they can save the country many of the 20 million lost working days a year—a loss about five times as great as that caused by all strikes.

Application forms and further details are available from Safety House, 60 Westbourne Grove, London, W.2.

Automation Analysis Department formed

Elliott Bros. (London) Ltd., a member of the Elliott-Automation Group, has created an Automation Analysis Department within its Data Processing Group of Divisions.

The company has accumulated extensive experience of both the ' on-line ' and ' off-line ' application of electronic computers to industrial processes through its computing service centres and through experience with ' on-line ' control installations by its computers both in this country and America.

The company states that in the great majority of cases it has found that there is no precise knowledge available of the true mathematical nature of industrial processes. This lack of knowledge of the nature of processes is one of the factors delaying the extensive introduction of complex automation systems. In America, Russia and certain other Eastern European countries the attitude adopted by industrialists is to install a computer to gather and evaluate the data available with the intention that, when the true natures of the processes involved have been determined, the computers will be put on to their operational control. In Britain the immediate incentives to adopt this course of action do not exist with the result that the introduction of automation is being delayed. To deal with this problem the Automation Analysis Department has been created under the leadership of Dr. L. C. Payne, to undertake the specialized studies involved in this kind of work.

Design appreciation courses for engineers

Continuing its efforts to bridge the gap between industrial design and engineering, the Council of Industrial Design is to hold two more design appreciation courses for engineers in the autumn.

A staff course will be held in two phases (October 23-27 and November 20-24) and one for executives from November 27 to December 1. Both will take place in the London area and, so as to make the fullest use of available time and encourage group discussion, will be residential. Details from Education Officer, COID, 28 Haymarket, London, S.W.1.

Radio telescope model presented to Science Museum

A scale model of the radio telescope at Jodrell Bank has been presented by the United Steel Companies Ltd. to the Science Museum. The presentation was made by Mr. A. J. Peech, deputy chairman and general managing director of United Steel, and the model was received on behalf of the Science Museum by Dr. H. H. Follett, director. The radio telescope was built by United Steel Structural Co. Ltd., of Scunthorpe, a United Steel subsidiary.

BISRA computer section

In recognition of the steady growth in the scope of its activities over recent years, the Computer Applications Section of BISRA's Operational Research Department has now been renamed the Systems Evaluation Section.

The duties of the new section, which will be headed by Mr. D. H. Kelley, B.SC., will be to carry out operational research investigations into the automation of large-scale systems. The immediate programme will be to study the automatic production planning and scheduling of various kinds of steelworks, and to investigate the information requirements of steelworks management.

COMPANY NEWS

Elcontrol Ltd. announces the conclusion between the company and the Siegler Corporation Magnetic Amplifiers Division of New York of an agreement for the exclusive sale and manufacture of Elcontrol products in the United States and Canada.

The Siegler Corporation have extensive sales coverage in the United States, and many manufacturing plants, with a turnover of approaching $100,000,000 per year.

The president of the Magnetic Amplifiers Division, Mr. Herbert Herz, has recently paid a visit to this country in order to conclude arrangements.

Hedin Ltd., of South Woodford, manufacturers of industrial electric heating equipment, have announced that as a result of continued expansion they have taken over additional office and works accommodation at Fowler Road, Hainault, Essex.

The manufacture of their industrial heating elements and resistances will continue to be carried out at South Woodford whilst furnaces and ovens will be made at Hainault.

Although the company was formed in 1930, it is only in the last six or seven years, under the direction of Mr. James Royce, that considerable progress has been made in the development and manufacture of electric furnaces. To enable Mr. Royce to devote more time to research and development work, Mr. Dennis Hobson has been appointed sales manager of the Furnace Division. Mr. Hobson, before joining Hedin Ltd., was assistant sales manager with Salem Brosius (England) Ltd.

Wild-Barfield Electric Furnaces Ltd. have rearranged some of their area representation to ensure more effective representation in England and Wales. The areas affected in which the undermentioned will also represent the Furnace Division of G.W.B. Furnaces Ltd. are as follows:

Birmingham and East Midlands Office, 71 Broad Street, Birmingham 15 (Midland 7232). Area manager, G. W. Haines. Sales engineers, R. E. Butchers and C. A. McNeill. The area covers the entire counties of Leicester, Northampton, Rutland and Warwick.

West Midlands Private address, 39 Peterdale Drive, Penn, nr. Wolverhampton (Wolverhampton 38450). Sales engineer, A. V. Skelsey. The area covers the entire counties of Shropshire, Stafford and Worcester.

South Wales Private address, Ty-Mawr, Peterston-super-Ely, Glamorganshire (Peterston 293). Sales engineer, T. M. Morgan. The area covers the entire counties of Brecknock, Carmarthen, Glamorgan, Pembroke and Monmouth.

Sheffield and North Midlands Office, 1 Clarkehouse Road, Sheffield 10 (Sheffield 62784). Area manager, E. J. Heiser, M.I.E.E. Sales engineers, D. N. Greensmith and D. J. Sutherland. The area covers the entire counties of Lincoln, Nottingham, Derby and Cheshire and the East and West Ridings of Yorkshire and Lancashire (south of Westmorland).

Northern England Private address, 7 Gordon Road, Redcar, Yorks. (Redcar 5197). Sales engineer, R. Flanagan. The area covers the entire counties of Cumberland, Durham, Northumberland and Westmorland and the North Riding of Yorkshire and Lancashire (north of Morecambe Bay).

PEOPLE

AT THE ANNUAL GENERAL MEETING last month of the British Standards Institution, **Mr. Geoffrey Cunliffe** was elected president of the B.S.I. in succession to Mr. R. E. Huffam.

Mr. Cunliffe is managing director of Norcros Ltd., the industrial holdings company. His connection with industry began in the 1920s with interests in the metal industries in Arizona and Mexico. In 1932 he joined the British Aluminium Co. Ltd. where, after five years, he was made deputy general manager and a year later appointed to the board.

On the outbreak of war he was seconded to the Ministry of Supply as Aluminium Controller and later he became a full-time member of the Board of Trade's Industrial and Export Council.

He returned to British Aluminium in a part-time capacity in 1944, being appointed general manager of the company. A year later he became joint managing director and, in 1947, deputy chairman. He continued in this office until the change of control in 1959, when he was appointed head of Norcros.

Mr. Cunliffe has served as a member of council, and as chairman or president of the Aluminium Development Association, the Aluminium Industry Council, the British Non-Ferrous Smelters Association and other organizations in the non-ferrous metals world.

In 1949 he was appointed chairman of the committee set up by the President of the Board of Trade 'to consider the organization and constitution of the B.S.I.'

Mr. Gerard Young, J.P., aged 51, who was recently elected as 326th Master Cutler, is the first Roman Catholic to hold this post.

Mr. Young is chairman of Tempered Group Ltd., which consists of six subsidiary companies which between them employ some 1,300 people. He joined Tempered Spring Co., now one of the six subsidiaries, in 1930 as management trainee at a salary of £1 per week. He was made a director in 1936, managing director in 1942 and became chairman on the death of his father in 1954.

Mr. Gerard Young, J.P.

The new Master Cutler takes a very keen interest in Sheffield civic activities, especially in the rapidly growing University of which he is Pro-chancellor, and in the hospitals.

He is a member of the Institute of Mechanical Engineers and one of the founder-members of the Coil Spring Federation, a technical body, and its research organization.

Mr. Frank T. Bagnall

Mr. Frank T. Bagnall, a well-known steel maker, who recently retired as electric furnace melting shop manager from Samuel Fox & Co. Ltd., Sheffield, and who put into operation the first of this country's large arc furnaces, has made his services available exclusively to Birlec-Efco (Melting) Ltd. Mr. Bagnall will help in the design and operation of all equipment manufactured by Birlec-Efco.

Dr. Franz R. Hensel, internationally-known expert in metallurgy and research administration, and until recently vice-president of engineering of P. R. Mallory & Co. Inc., Indianapolis, Indiana, has joined the Clyde Williams & Co., Columbus, Ohio, and its associated technical, management service and financial enterprises.

In the new position, Dr. Hensel will be president of the Clyde Williams Corporation and executive vice-president of Clyde Williams & Co., the parent organization to the various subsidiary operations of the firm.

Dr. Hensel, who was born in Germany in 1904, has had a varied career in metallurgical research, product development and the engineering of materials. A graduate of the Royal Gymnasium in Dresden and the Mining Academy in Freiberg, he also studied at the University of Sheffield, England, and at the Technische Hochschule, Charlottenburg, Berlin, receiving his doctorate in engineering from the latter institution. Coming to the United States in 1929, he joined the Westinghouse Laboratories, where he conducted studies on age-hardening phenomena in copper alloys, austenitic steels and arc-welding deposits. He became associated with P. R. Mallory in 1934 as metallurgical consultant and progressed through that company to the vice-presidency of engineering. Dr. Hensel's work at P. R. Mallory led to more than 150 patents, issued in the United States and Europe, covering such subjects as refractory metal compositions, electric contact materials, brazing alloys, copper alloys, bearing materials, sintering and diffusion processes, metal/non-metal compositions and bimetallics. He was associated with much of the early work conducted in the United States on titanium, tungsten, molybdenum and semi-conductor materials.

Mr. A. C. Sturney has been elected to the board of the International Nickel Co. (Mond) Ltd. He relinquishes his appointment as general manager of publicity.

Mr. Sturney joined the International Nickel Co. in 1927 as their representative in London, with the task of

forming the first Bureau of Information on Nickel. On the merger between Inco and Mond in 1929 he became responsible for U.K. publicity. He was made general manager of publicity in 1954.

Mr. Sturney began his metallurgical and mining studies with the Royal School of Mines, graduating with a B.Sc., and subsequently worked at the National Physcial Laboratory under Dr. W. Rosenhain.

Mr. Sturney will be succeeded as general manager of publicity by **Mr. L. F. Denaro,** who will relinquish his appointment as assistant to the managing director.

Mr. D. Parry Davies has been appointed a director of Mond Nickel (Retirement System) Trustees Ltd. and is succeeded as comptroller of the International Nickel Co. (Mond) Ltd. and Henry Wiggin & Co. Ltd. by **Mr. L. C. H. Voss.**

Mr. C. W. R. Edwards has been appointed secretary of the International Nickel Co. (Mond) Ltd. and Henry Wiggin & Co. Ltd. in succession to **Mr. E. Vaughan.** Mr. E. Vaughan remains a director of both companies.

The Incandescent Group of companies has appointed **Mr. W. S. Sinclair** to be manager of its Cardiff office as of the beginning of August.

Mr. Charles W. Brunstetter has been appointed general manager of Ipsen Industries Inc.

Mr. Brunstetter joined Ipsen Industries in September of 1960. He has been responsible for the development of the Refractory Metals Division of Ipsen Industries and served as manager of the division. Prior to joining the firm, Mr. Brunstetter was vice-president of Astrometals Corporation of Hawthorne, New Jersey. He has carried out research and development projects with NASA in the use of refractory metals for space age requirements. He has also been associated the Thermionic Products Co. of Plainfield, New Jersey.

B. & S. Massey Ltd. advise the retirement of **Mr. Denis L. Perry,** sales manager, after over 48 years' service with the firm.

Mr. J. H. Callagham, who joined the company in 1937, becomes sales manager, and **Mr. E. R. Beesley** assistant sales manager.

Mr. D. R. Walker, A.C.C.S., has been appointed secretary of the Vitreous Enamel Development Council, and the registered offices have been transferred from 11 Ironmonger Lane, London, E.C.2, to 28 Welbeck Street, London, W.1 (Hunter 2237).

British Insulated Callender's Cables Ltd. regrets to announce the death last month of **Mr. Samuel Bellis,** sales manager (central marketing) of BICC. He was aged 63 and died in hospital at Cobham, Surrey.

Mr. R. B. W. Holland, formerly general manager of Head Wrightson Stockton Ltd., has been appointed London manager of Head Wrightson & Co. Ltd.

Mr. J. D. Eccles has been appointed director and general manager of Head Wrightson Stockton Ltd.

Mr. G. F. Taylor has been appointed general manager of Head Wrightson Steel Foundries Ltd.

Mr. A. J. Long has joined the Head Wrightson Export Co. as general manager.

Mr. E. J. Robinson has been appointed a director of the Head Wrightson Export Co. Ltd., which is responsible for the development of trade in overseas markets for the Head Wrightson companies.

Mr. R. F. N. Otway has joined the Head Wrightson Export Co. Ltd. as manager (Europe). Before taking up this appointment Mr. Otway was with the Morgan Crucible Co. Ltd.

Mr. G. Paterson has been appointed personnel manager of Head Wrightson & Co. Ltd.

Sanders & Forster Ltd., of Stratford, London, and Barking, Essex, the standard steel building and structural engineering company of the Chamberlain Group of Building Construction, Engineering and Property Companies at 3 Buckingham Palace Gardens, London, S.W.1, announces the appointment of an additional director to the board.

Formerly the company's general sales manager, **Mr. J. F. D. Wood,** A.M.I.C.E., has now been appointed sales director.

Mr. Wood joined the company in 1954 as erection manager and was appointed home sales manager in 1957. In 1958 he became sales manager and he was made general sales manager early this year.

Mr. H. C. H. Matthews, B.SC., A.M.I.E.E., has been appointed a technical director of Pantak Ltd., of Vale Road, Windsor, Berks.

Dr. J. E. Holmstrom, who has recently joined Pergamon Press, has had a varied career. After beginning as an engineer on railway construction and surveying in China and Malaya he worked as a bridge designer in London, and whilst so engaged obtained his doctorate for a thesis on the economics of transport. Then came some years on technico-economic investigations in the Development Department of I.C.I. After war service, holding military staff appointments, he returned to I.C.I. in charge of the Central Registry for correspondence and technical information. From 1950 to 1958 he worked in the Department of Natural Sciences of UNESCO as specialist for questions of documentation and multilingual terminology.

In Pergamon Press Dr. Holmstrom becomes secretary-general of the Scientific Conference Centre, now established to assist the organisers of international meetings. In addition he will edit certain other special categories of publications such as those relating to information work, multilingual special dictionaries, and possibly translations of Chinese science.

The George Cohen 600 Group Ltd. announces that **Mr. John P. Bolton** has been appointed managing director of its Australian subsidiary, George Cohen, Sons & Co. (Australia) Pty. Ltd., of Sydney. He succeeds the late Mr. C. A. Bell. Mr. Bolton has been associated with the 600 Group since 1946.

Mr. John T. McCarley, director of manufacturing—international, has been appointed managing director of the British Division of the Yale & Towne Manufacturing Company. Mr. McCarley, who is 52, joined Yale & Towne in 1936, in Detroit, Mich. He succeeds Mr. John O. Sewell, who has resigned his position in order to accept an executive position with a prominent British company. Mr. Sewell will remain with Yale & Towne in an advisory capacity until taking up his new appointment on September 1.

After 48 years' service with the General Electric Co. Ltd., **Mr. A. B. Price,** B.SC., A.M.I.MECH.E., sales manager of the company's engineering works at Erith, retired last June. To mark the occasion a cheque was presented to Mr. Price, on behalf of G.E.C., by the general manager of the Erith engineering works, Dr. K. J. Wootton. The many friends and colleagues of Mr. Price also recognized him by subscribing to a walnut cocktail cabinet.

Electrical Aids in Industry *Data Sheet* **No. 18**

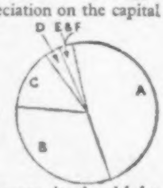
Factory Heating-1

The space heating of factories by electrical means can be achieved in a variety of ways which will be dealt with in the next Data Sheet.

Before deciding on any form of factory space heating—whether by means of electricity or not—it is as well to have clearly in mind all the components of the total annual running cost, and not merely the fuel cost, of the heating installation.

They are:

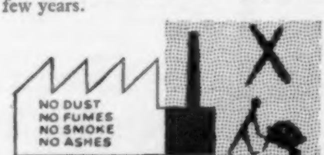
(A) The cost of the fuel or the electricity,
(B) Interest and depreciation on the capital cost of the installation,
(C) Labour,
(D) The cost of running auxiliary plant such as fans and pumps,
(E) Maintenance,
(F) Insurance.



In comparing fuel costs it should be borne in mind that electric heat is refined heat and has had all the fuss, bother, dirt, and cost of the conversion of fuel into heat taken out at the generating station.

In arriving at the true figures for capital cost and depreciation, maintenance and insurance, those connected with such items as boilerhouse, chimney, fuel store and access road should be included; labour costs should include such tasks as ash disposal. None of these items occurs when electricity is used, although space will be required for the electric boiler and storage vessels in the case of the type (h) in the next column.

Electricity provides the ideal answer to the requirements of the Clean Air Act, the impact of which has introduced an important new factor during the last few years.



The following list gives the main types into which electric heating installations fall:

(a) High temperature ("infra-red") overhead heaters operating at near red heat.

(b) Medium temperature panels operating at surface temperatures of 400° to 600° F.

(c) Extended surface heating in the shape of floorwarming operating at temperatures up to 80° F.

(d) Oil and water filled radiators.

(e) Tubular heaters.

(f) Unit heaters.

(g) Storage block heaters.

(h) Electric boilers and water heaters operating in conjunction with hot water radiators or panels either with or without water storage.

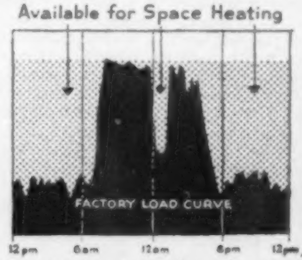
All these methods of electric heating can be divided into two distinct classes:

(a) Those that utilise electricity during "off-peak" hours and store the heat so generated for use at a later period.

(b) Those that use electricity whenever the heating system is in use (i.e. direct electric heaters).

The use of a heat storage system in a small works on a block tariff takes advantage of the lower tariff offered for an off-peak supply, and in the larger factory on a Maximum Demand tariff means that the heating load will not incur any M.D. charge. Alternatively

Available for Space Heating



there may be cases where the use of direct electric heaters can be integrated with other factory loads in such a way that they are not used during the factory peak periods and will thus incur no additional M.D. charge.

CUT HERE

NEW PLANT

Non-contact gauges

To KEEP pace with the need in industry for improved quality control and high production speeds, many manufacturers have been turning to non-contact gauges to improve dimensional tolerances during production. Recently one of the largest manufacturers of this type of gauge, the American Daystrom company, established a U.K. technical sales and service facility at Gloucester known as Daystrom Ltd. Several basic models of gauge-utilizing X-rays, infra-red rays and visible light for the measurement of thickness, width, diameter or profile of material are produced by Daystrom. The X-ray gauge is used primarily with rolled or extruded products and is suitable for a wide variety of materials in this field.

The gauge is known as the XactRAY and consists of three basic elements, an X-ray generator, which directs controlled beams of X-rays through the material being measured, the X-ray incident unit or pick-up, which converts the transmitted electromagnetic energy into an electrical signal, and an electronic console, which computes and converts the signal into meter indications. Dimensional changes are displayed as a deviation from the pre-set nominal thickness on an indicator calibrated in any unit of density or thickness. A signal proportional to thickness deviation is available to operate automatic thickness control, data-logging devices, and strip chart recorders for permanent records, or marking of off-gauge material.

Equipment

The X-ray generator and pick-up unit are mounted on opposite sides of the material which is being measured. Units are usually mounted on a steel 'C'-type frame so that their distance apart is fixed; this distance varies, depending on the application, between 6 and 36 in. The frames can be mounted on wheels and motorized to allow positioning of the X-ray beam at any point across the width of the material being gauged. In installations where space is limited, the X-ray generator and pick-up unit can be permanently mounted in the production machine. One of the features of the XactRAY is its compact design. For example, a gauging carriage to measure up to 0·150in. in carbon steel or 2 in. in aluminium, is only 6 in. wide.

Both X-ray generator and pick-up unit have been designed to operate under severe mill conditions and are sealed against oil, water and steam. In situations where they are liable to mechanical damage, special armoured gauges are available.

The electronic console is preferably located in the motor room within 100 ft. of the X-ray source. Positive filtered air pressure is, however, maintained within the cubicle to ensure reliability in locations where airborne dust and dirt are prevalent. All electronic components are mounted on a special hinged modular chassis to permit inspection during operation.

Thickness setting

A patented feature of the XactRAY is a device for inserting metal standards into the X-ray beam for calibration purposes. These standards are enclosed in a sealed chamber directly above the X-ray source and are inserted into the beam by rotary solenoids. The system enables an operator at a remote position to select the exact thickness to be measured in increments as small as 0·0001 in. Normally, the XactRAY can be set to a new thickness range in less than 10 sec., including time for recalibration. Where materials of different densities are to be gauged, a multi-position selection switch, which automatically compensates for any variation of density, is provided.

Performance

Five models of the gauge give a range from 0·00035 in. for aluminium foil to 2-in. steel plate; any one model has a thickness range of up to 200 : 1 (a 60-kV. X-ray generator is suitable for 0·010–2·00 in. of aluminium). Accuracy is better than $\pm 1\%$ of the thickness being measured and to special order this figure can be improved to 0·5%. Stability is guaranteed for at least 8 h.

SITUATIONS VACANT—continued

ICI

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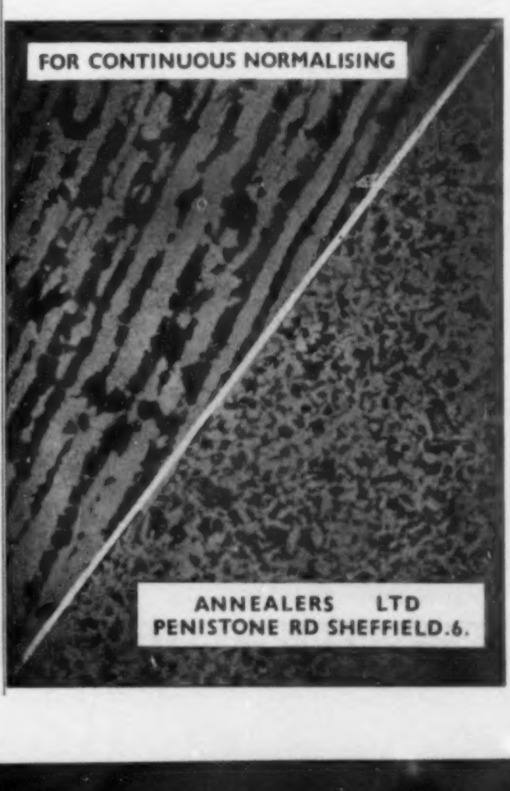
Two—HEENAN & FROUDE TYPE P.66 OIL-COOLER UNITS, complete in all details; condition unused. Two—Vickers-Detroit Hydraulic Pumps, Type V.105.C.—Whitefield Machinery & Plant Ltd., 48 Chatham Street, Edgeley, Stockport.



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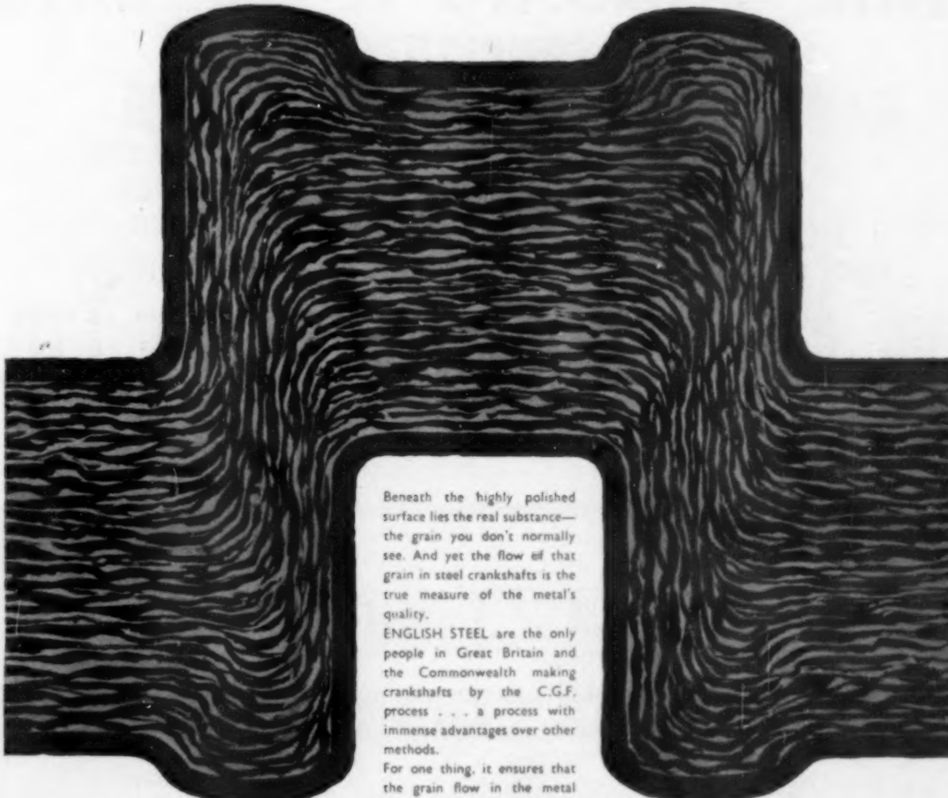
IT'S THE GRAIN THAT TAKES THE STRAIN



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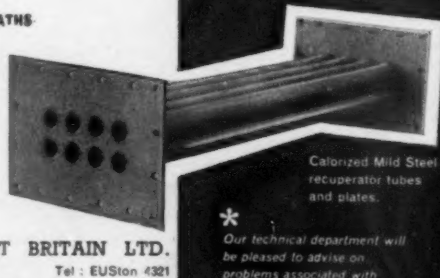

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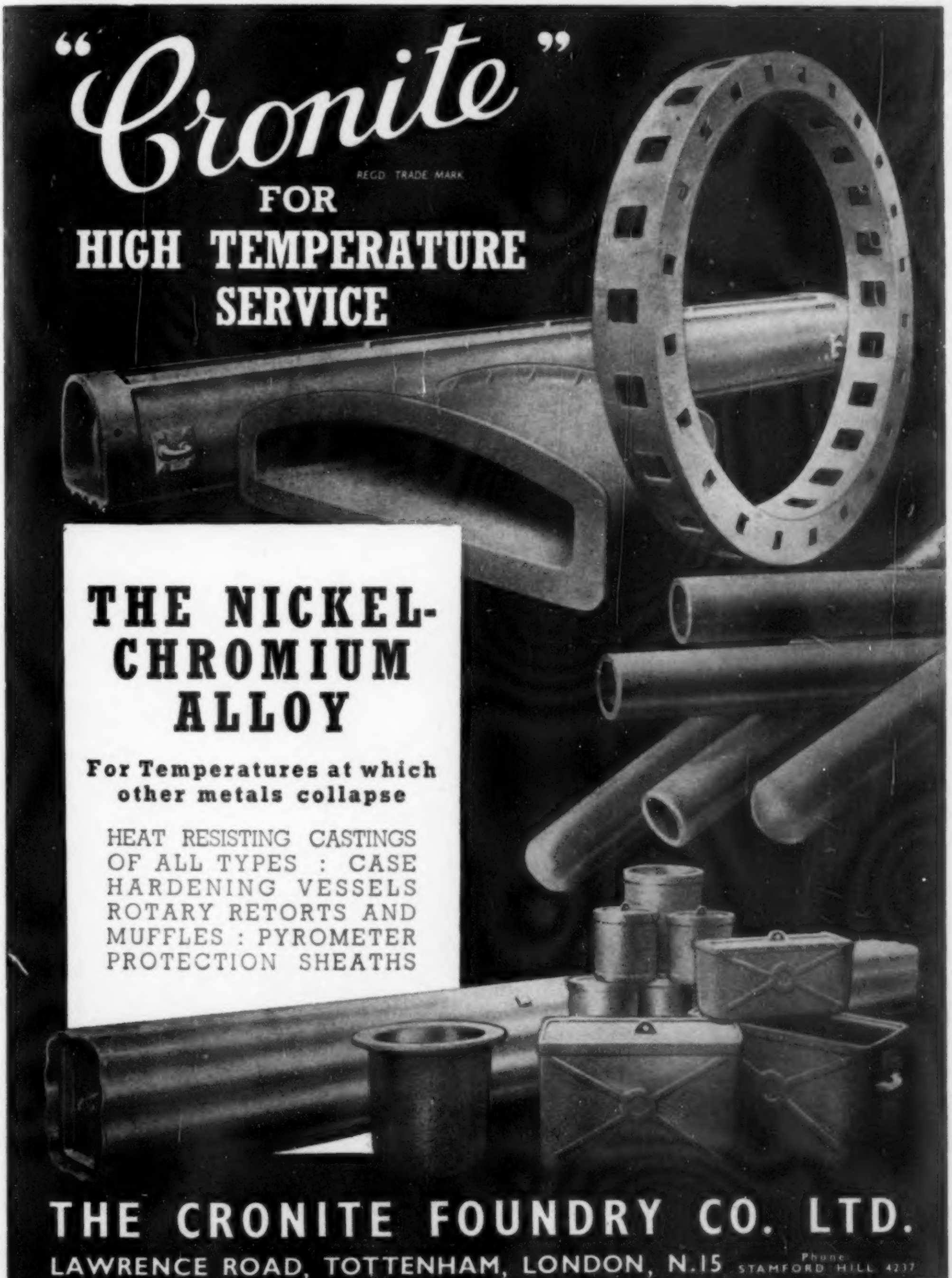
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